European Commission
Sixth Framework Programme

Project no. **015403**

FONIO

Upgrading quality and competitiveness of fonio for improved livelihoods in West Africa

Specific targeted research project (STREP)

INCO (Specific International Scientific Cooperation Activities)

Second activity report

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Project coordinator organisation name:
CIRAD (International Cooperation Centre in Agronomic Research for Development) - France

February 2008

This report gives an overview of the actions carried out in the different workpackages during the reporting period. It was elaborated with collaboration of all project staff and particularly with following scientists:

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To all the contributors, both listed and unlisted, we are truly grateful

Jean-François CRUZ – Project coordinator – Cirad - France

Nota:

- The activities presented in this report have been funded with support from the European Commission within the framework of the FONIO project.

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Executive summary

Context

Traditional cereals constitute the staple diet of many African populations and regions, especially in the most isolated rural areas, and play an essential role in providing food for the poorest populations. They are well suited to local conditions, being reasonably resistant to drought, and help to maintain the environment by providing a covering of vegetation on ground which is ecologically fragile, and considered of little value.

Among traditional cereals, fonio (*Digitaria exilis*), is considered as the most ancient indigenous West African cereal. Nowadays, fonio still grows in farmers' fields in a vast area extending from Senegal to Chad mainly on eroded lateritic soils. In West Africa, farmers cultivate mainly white fonio *(Digitaria exilis),* which is also called fundi, findi, acha or "hungry rice". The term 'hungry rice' well describes the role of this little plant in local population life. Fonio supplies to several million people food early in the growing season, when main crops are still too immature to be harvested and when other food resources are scarce. Fonio consumption varies between years and seems to be dependent on the availability of other cereals. When other cereals are not available, for example due to a failing harvest, fonio consumption is high, and thus fonio consumption could be considered as one of the coping strategies for increasing household food security.

The relative stagnation of production is partly explained by a lack of research and development devoted to this product. In order to ovoid the decline of this commodity, it is important to solve the many problems after the harvest, in particular by perfecting post-harvested techniques and by improving the quality and the follow-up of sales and distribution.
Today, fonio is produced by small enterprises and sold not only on local urban markets, but also to Africans emigrated in Europe and in United States. Indeed several small private enterprises, notably in Mali and Burkina, have been set up to cater for the export markets. There is strong consumer demand for fonio due to its nutritional qualities, and because it helps to satisfy the demand for a more varied cereal diet.

That is the reason why a research/development project named *FONIO - Upgrading quality and competitiveness of fonio for improved livelihoods in West Africa-* was elaborated to achieve the following objectives. The FONIO project started formally at January 1, 2006 per three years duration.

Objectives

FONIO's objective is to upgrade quality and competitiveness of fonio in West Africa by improving production (adapted varieties, appropriated production and farming systems, ...), technology (innovation in post-harvest mechanisation and processing,...) and marketing systems for local and export markets. In Africa, the increasing interest for fonio, as well from consumers than from small enterprises, demonstrates the possibility for the development of good quality products based on fonio. For European consumers, the desirable criteria are nutritional quality, originality, healthier properties and environmental friendliness. The production of exportable value added fonio products is conceivable and must be promoted.

To achieve the overall objective, FONIO project promote an interdisciplinary and innovative approach involving scientists from various backgrounds: food technology, nutrition, process engineering, mechanization, social sciences, and agronomy. It support research/development actions with a participatory approach involving producers, processors, women's groups and small enterprises that will benefit directly and quickly from the research results.

The main research activities (workpackages) of the project are the following:
WP1 - Diversification of fonio products for niche export markets and local markets
WP2 - Nutritional aspects of fonio and fonio products
WP3 – Demand for new products and its effects on income generation and distribution
WP4 - Small scale enterprises and innovation in product and process
WP5 - Opportunities for diversification and multipurpose uses of fonio in crop-livestock systems
WP6 - Improving knowledge on fonio based cropping systems and ways for improving productivity

Participants

Research scientists are from three European countries and four West African developing countries (Mali, Guinea, Burkina Faso and Senegal). They belong to Research centres, Universities, National or International Research Systems.
Three from European countries:
Participant 1: Cirad (International Cooperation Centre in Agronomic Research for Development) France,
Participant 2: Wageningen University (Division of Human Nutrition) The Netherlands,
Participant 3: CRA-W (Walloon Center of Agricultural Research) Belgium.
Four participants from West African countries:
Participant 4: IER (Institut d'Économie Rurale) Mali.
Participant 5: IRAG (Institut de Recherche Agronomique de Guinée) Guinée.
Participant 6: CIRDES (Centre International de R&D sur l'Élevage en zone Subhumide) Burkina Faso.
Participant 7: ENDA-GRAF (Groupes Recherches Actions Formations) Sénégal.

The co-ordinator of the project is Jean-François CRUZ, CIRAD, UMR Qualisud "Integrated food quality systems" Maison de la Technologie, 73 rue Jean-François Breton. 34398 Montpellier Cedex 5 - France
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Work completed

Co-ordination and management

The first annual coordination meeting was held in Cirad Montpellier, France, from 4 to 8 December 2006. Organized by the Cirad project coordination, this meeting was attended by about twenty people (Steering Committee and scientists) coming from Mali (IER), Guinea (IRAG), Senegal (ENDA Graf), Burkina Faso (Cirdes), Netherlands (Wageningen University), Belgium (CRAW) and France (Cirad). The meeting was dedicated to present and analyse the first research results obtained during the first year and to prepare and plan the scientific activities for the second year of the project.

During year 2007, the first 2 months were devoted to reports writing (first activity and first management reports) with collaboration of WPs and team leaders. Then different meetings were organized during the year: "WP6 meeting" in Bamako (April, 3-4/2007), "WP3&4 workshop" in Bamako (May 29- June 2/2007), "WP5&6 workshop" in Mali and Burkina Faso (October 16- 26/2007), "WP1 to 4 workshop" in Bamako (Oct. 29- Nov. 3/2007). Two specific missions were also realised: in Mali and Burkina Faso (March 6-13/2007) to study fonio precooking and in Guinea (April 16-27/2007) to analyse the Guinean fonio commodity chain in collaboration with WP3 and WP4.

Lastly, the second annual coordination meeting took place at CRAW Center (Walloon Center of Agricultural Research) in Libramont (Belgium) on 25-29 November 2007. This meeting was attended by the project Steering Committee with representatives of each partner. The 4 days meeting was dedicated to present and analyse the research results obtained during the second year, to prepare the activities for the last year of the project and to plan the submission of reports and deliverables.

Nota bene: The scientific coordinator of the project (J.F. Cruz) based in Bamako (Mali) since the beginning of the project joined Cirad Montpellier (France) on September 1, 2007.

Research activities

Research Activities were conduced in the framework of the 6 thematic work packages. Activities of WP1 to WP4 were going on all along the year while WP5&6 conducted the major part of their operations (on-station trials, diagnosis of cropping and production systems, etc) during the agricultural season, from sowing (June-July) to harvesting (September-October)

WP1, coordinated by Cirad (France), concerns "Diversification of fonio products for niche export markets and local markets". During 2007, workpackage 1 focused on task 1.2. with the optimization of parboiling process at laboratory level. A diagram was developed in Cirad laboratory using small quantities of grain and analytical methods were adopted. Preliminary experiments were conducted to define study limits of influent factors before running a Doehlert experimental design with three factors and 15 experiments. Response surface methodology and desirability function were used to define optimal conditions to get a good technological quality product. Other parboiling tests were carried out in parallel in IER controlled conditions to study the effect of soaking water pH, temperature and soaking time on paddy grain water content and milled grain colour. In Mali and in Burkina Faso, tests were implemented at SME level to increase knowledge of traditional precooking and to draw up the diagram of fonio precooking. Task 1.3 focused last year on the manufacturing of two driers : a counter current cross-flow gas drier (CSec-T) and a greenhouse ventilated solar drier (CSec-Serre or "Fama"), continued the second year through experiments conducted in local enterprise conditions during two different seasons (dry and humid). Their performances were compared to that of other gas and solar driers. Processors were asked to validate these equipments. Task 1.4. started the second year with the analysis of 54 fonio ecotypes collected by WP6 and WP5 in Mali, Guinea, Burkina Faso. These varieties were characterized at physical and biochemical level. Their dehulling, milling and cooking properties were determined. A Principal Component Analysis run on five quality traits showed a variability of these traits among the ecotypes per country.

Wageningen University is leading WP 2 "Nutritional aspects of fonio and fonio products". The activities of WP2 in 2007 were mainly focused on implementation of substudy 1 (nutrient value of fonio and fonio products), substudy 2 (food consumption and role of fonio in dietary patterns) and substudy 3 (contribution of fonio to nutrient intake and nutrition status). Samples of fonio varieties and fonio products were collected and prepared for biochemical analysis. Food consumption studies (24 hour recall and food weighed records) were carried out among 100 and 30 women of reproductive age in Bamako respectively. Nutritional status and blood sampling was carried out among 67 women. A study on the identification of factors predicting the consumption of fonio among women of reproductive age in Bamako was carried out. Nutritional status of these women was determined and blood was withdrawn of the women to determine iron status. The Mali food composition table was updated. Preliminary data show that iron deficiency is highly prevalent among women of reproductive age in Bamako, probably due to a low iron intake from the diets. Women do consume fonio, but frequency and portion size of fonio is low. Fonio consumption could be promoted by focussing on positive attitudes towards fonio consumption, emphasizing general health consequences of fonio consumption and by reducing the barriers to consume fonio. Whether iron status could be increased by increasing fonio consumption is depending on iron and phytate level of fonio and fonio products, and the effect on these by parboiling.

WP3 led by Cirad concerns "demand for new products and its effects on income generation and distribution". During 2007, the processing of data (price paid for quality characteristics and profile of consumers) collected in 2006, in Bamako, was finalized within the framework of the task 3.1. (demand for new products in Africa). It was shown that the market of new products (milled and washed or precooked fonio) reached different consumers from those who usually buy decorticated or milled fonio. They were more often men and they have usually a high level of education and status. A paper about the valuation of quality attributes on the retail market in Bamako was published. A new survey focused on potential consumers of precooked fonio in Bamako was launched in November. Concerning task 3.2 (demand for new products in Europe), a survey about the demand for new products and new quality attributes (fair trade, organic, etc) was realised in Montpellier (France). The results showed that, on average, consumers tend to look for beautiful packages, with information and labels. The multiplication of labels is attractive for most consumers, except for label: "small farmers" and "African origin" at the

same time. The test of recipes showed that non connoisseurs of fonio do not succeed 50% of the time. An effort on recipe still has to be done. The results suggested to find simple recipes such as "polenta" (soft porridge) adapted to south European food habits. Concerning the market chains (task 3.3), new surveys and interviews were done with small scale processors and different stakeholders of the market chain in Mali and in Guinea. A first assessment of the jobs created by producers of precooked fonio and the millers was done. Difficulties were encountered to draw a comprehensive map of the market chain, and to assess the margins of the different stakeholders.

WP4 is led by ENDA Graf (Senegal) and concerns "small firms and innovation in terms of products and processes". Fonio producing MSEs that developed in the recent years are confronted to major contradictions, including the desire to expand in environments where fonio itself is more or less marginalized by public policies and the departments of agriculture of the respective countries. But the impacts in terms of social and economic dynamics are real. A female leadership has been consolidated in the management of the sector. Women are more present in collecting and distributing finished products. Over 90% of companies are led by women and most of the people mobilized for SME activities are women. They share about 70% of the generated incomes, which are still low however. Fonio seems to become a niche. But several constraints including the removal of the sand, washing, the development of networks of qualified workers for the construction and dissemination of equipment, the technical and financial capacity of enterprises, regular and quality supplies, the better control of distribution networks, are challenges still to overcome.

WP5, directed by CIRDES (Burkina Faso) is named "Opportunities of diversification and multiple uses of fonio in production systems". In 2007, the diversity of fonio producers in Guinea, Mali and Burkina Faso was characterized in accordance with the agro-climatic zones (food shortage farming in semi-arid zone, crop diversification farming in the sub-wet zones). The mode of fonio farming was characterized by a monitoring of farming lands in Guinea, Mali and Burkina Faso (farming without input, producing 600 kg/ha grain on average) as well as the factors of variations of the output (contribution of organic manure, early weeding, covering up grass, age of the field…) and identifying the intervention priorities on the exploitations and on the modes of farming. The strategies of fonio producers started to be analyzed as well as the socio-technical environment of the production of fonio (requests and service offers). Two opportunities are offered to the fonio producers: the first one is to sale on the local market, but for that to happen, farmers need to lower the selling price of the fonio by the mechanization of the post-harvest activities (threshing, dehulling); the second opportunity is to export to the "organic fair trade" markets via new economic operators and, for this market, farmers need to increase the productivity of the fonio (possible output of 1000 kg/ha) by an ecological intensification (organic manure, productive local varieties, early mechanical weeding…) to preserve its character of "organic (or biological) farming". The experiments on the valorisation of straws and the improvement of the productivity are planned for 2008.

WP6 is led by CRAW (Belgium) and involves IRAG, IER, CIRAD and CIRDES. The aim of WP6 is to find out more about fonio-based cropping systems and look at ways of improving productivity, in line with the production chain's expectations.

Variety trials highlighted the large variation existing amongst the different cultivars tested. Two varieties, *Kökounin* and *Gbelen* from the early heading group presented good performances in the two experimental sites in Guinea. In the late heading varieties, *Konso* and *Siragué* performed well. In 2007, a multi-local varieties comparison trial included 13 varieties in 4 sites (two in Guinea and two in Mali). After the adaptation of different technologies, in order to measure thousand grains weight, to scan NIRS spectra of these grains, …., morphological and biochemical characterisation of these varieties, started in 2006, was continued in 2007 together with the characterisation of their technological value (WP1).

The analysis of 2006 results of the trials aiming to test fonio responses to photoperiod and its impact on biomass distribution has underlined the photoperiodism of this species with a flowering induction under shortening day length. Nevertheless, each variety was characterized by its own intrinsic cycle length. These data were used to calibrate the model developed by Folliard et al. (2004) to predict the shift from the vegetative to the reproductive stage of photoperiodic species.

Exploratory fertilisation trials have led to the conclusions that N, P, K fertilisation could have a positive impact on fonio production. 2007 trials focussed on NPK fertilisation of the Fonio in crossing three levels (0, 15 and 30 units/ha), of each nutrients. The three experimental sites were Bordo and Bareng, in Guinea, and Cinzana in Mali.

The exchanges with fonio producers underlined that both fertilisation and weed control within fonio crops have to be elaborated in the context of the crops rotation scheme. Difficult after fallow, control is possible when this crop comes after a leguminous species profiting from the back effects of the rotation head (Sorghum, Millet,...) if they received manure. Such rotation scheme seems to maintain enough fertility for the fonio in order to reduce the pressure exerted by *Striga hermontica* occurring mainly on poor soils.

Dissemination of knowledge

Fonio producers and processors are the final target of the FONIO project and need to be informed about the different tasks. The implementation and the first results of the research activities have been presented to different stakeholders during the specific workshops organized during the year. So, during the WP3&4 workshop on May in Mali, some processors from Bamako were invited to participate to the meeting. During the "post rainy season" workshop on October in Mali and Burkina Faso, project' staff met producers leaders in some villages to present FONIO project. On April, during a mission in Guinea, the Project coordinator and scientists from WP3, WP4 and WP6 got also the opportunity to take part in a documentary on fonio processing and to participate in a radio programme about fonio channel in Guinea. This radio programme will be diffused to a large audience by local rural radio stations in the country.

For other stakeholders (professionals, scientists, policy makers, decisions makers,...), project leaflets were distributed during meetings (e.g. with Agriculture Minister in Guinea, with The French ambassador in Mali, ..) or during Agricultural or Scientific Shows (SIAGRI and Smara in Mali, ...). Some papers or posters were also published:

Dury S., Meuriot V., Fliedel G., Blancher, Boré Guindo F., Dramé D., Bricas N., Dialité L. et Cruz J.F., 2007. The retail market prices of fonio reveal the demand for quality characteristics in Bamako, Mali. Communication at 106th seminar of the European Association of Agricultural Economists "Pro-poor development in low income countries: Food, agriculture, trade, and environment", Montpellier, France, 25-27 October, 15 p.

Koreissi Y., Brouwer I., Hulshof P., Zimmermann M., 2007. Nutritional aspects of fonio and fonio products. Poster *in* 7th International food data conference. Food Composition and Biodiversity. Sao Paulo, Brazil, October 21-24, 2007.

For larger public information, the WEB site is developed (http://inco-fonio.cirad.fr) and, since the beginning of the project, several web pages have also been produced on the European FONIO project:

"Cirad" or Agropolis pages
http://www.cirad.fr/en/actualite/communique.php?id=501
http://umr-qualisud.cirad.fr/projet_de_recherche/axe_1_theme_1_1/amelioration_de_la_qualite_de_la_filiere_fonio
www.agropolis-international.net/pdf/lettre/lettre_122.pdf

"CRAW" pages
http://www.cra.wallonie.be/module/newsletter/index.php?ID=76&Action=view
www.cra.wallonie.be/module/craw_info/craw_info_pdf/craw-info-16-2007.pdf

"European Union" pages
http://ec.europa.eu/research/headlines/news/article_06_09_22_en.html
http://cordis.europa.eu/fetch?CALLER=EN_NEWS&ACTION=D&SESSION=&RCN=26409

Other Web pages
http://www.underutilized-species.org/record_details.asp?id=701
http://www.underutilized-species.org/MasksSearch/SearchProjectDetail.aspx?id=227
http://www.seedquest.com/News/releases/2006/august/16742.htm

Section 1 – Project objectives and major achievements during the reporting period

General project objective and current relation of the project to the state-of-the-art

The overall objective of FONIO project is to upgrade quality and competitiveness of fonio in West Africa by improving production (adapted varieties, appropriated production and farming systems, ...), technology (innovation in post-harvest mechanisation and processing,...) and marketing systems for local and export markets. In Africa, the increasing interest for fonio, as well from consumers than from small enterprises, demonstrates the possibility for the development of good quality products based on fonio. For European consumers, the desirable criteria are nutritional quality, originality, healthier properties and environmental friendliness. The production of exportable value added fonio products is conceivable and must be promoted.

Traditional cereals constitute the staple diet of many African populations and regions, especially in the most isolated rural areas, and play an essential role in providing food for the poorest populations. They are well suited to local conditions, being reasonably resistant to drought, and help to maintain the environment by providing a covering of vegetation on ground which is ecologically fragile, and considered of little value.

Among traditional cereals, fonio (*Digitaria exilis*), is considered as the most ancient indigenous West African cereal. Nowadays, fonio still grows in farmers' fields in a vast area extending from Senegal to Chad mainly on eroded lateritic soils. The total area under production is estimated at 350 000 hectares, and production reaches 250 000 tons per year with average yields of about 700 kg/ha. For many rural populations fonio is a staple food especially for communities in the mountainous areas of Fouta Djalon in Guinea. Farmers in Mali, Burkina Faso, Ivory Coast, Nigeria, Senegal,... also cultivate this small cereal. In West Africa, farmers cultivate mainly white fonio *(Digitaria exilis),* which is also called fundi, findi, acha or "hungry rice". The term 'hungry rice' well describes the role of this little plant in local population life. Fonio supplies to several million people food early in the growing season, when main crops are still too immature to be harvested and when other food resources are scarce. Fonio consumption varies between years and seems to be dependent on the availability of other cereals. When other cereals are not available, for example due to a failing harvest, fonio consumption is high, and thus fonio consumption could be considered as one of the coping strategies for increasing household food security.

The relative stagnation of production is partly explained by a lack of research and development devoted to this product. In order to ovoid the decline of this commodity, it is important to solve the many problems after the harvest, in particular by perfecting post-harvested techniques and by improving the quality and the follow-up of sales and distribution.

Today, fonio is produced by small enterprises and sold not only on local urban markets, but also to Africans emigrated in Europe and in United States. Indeed several small private enterprises, notably in Mali and Burkina, have been set up to cater for the export markets. There is strong consumer demand for fonio due to its nutritional qualities, and because it helps to satisfy the demand for a more varied cereal diet.

To achieve the overall objective presented above, FONIO project promote an interdisciplinary and innovative approach involving scientists from various backgrounds: food technology, nutrition, process engineering, mechanization, social sciences, and agronomy. It support research/development actions with a participatory approach involving producers, processors, women's groups and small enterprises that will benefit directly and quickly from the research results.

The workplan is divided into 6 workpackages gathering the following research activities:

WP1 - Diversification of fonio products for niche export markets and local markets
WP2 - Nutritional aspects of fonio and fonio products
WP3 – Demand for new products and its effects on income generation and distribution
WP4 - Small scale enterprises and innovation in product and process
WP5 - Opportunities for diversification and multipurpose uses of fonio in crop-livestock systems
WP6 - Improving knowledge on fonio based cropping systems and ways for improving productivity

presented graphically as below:

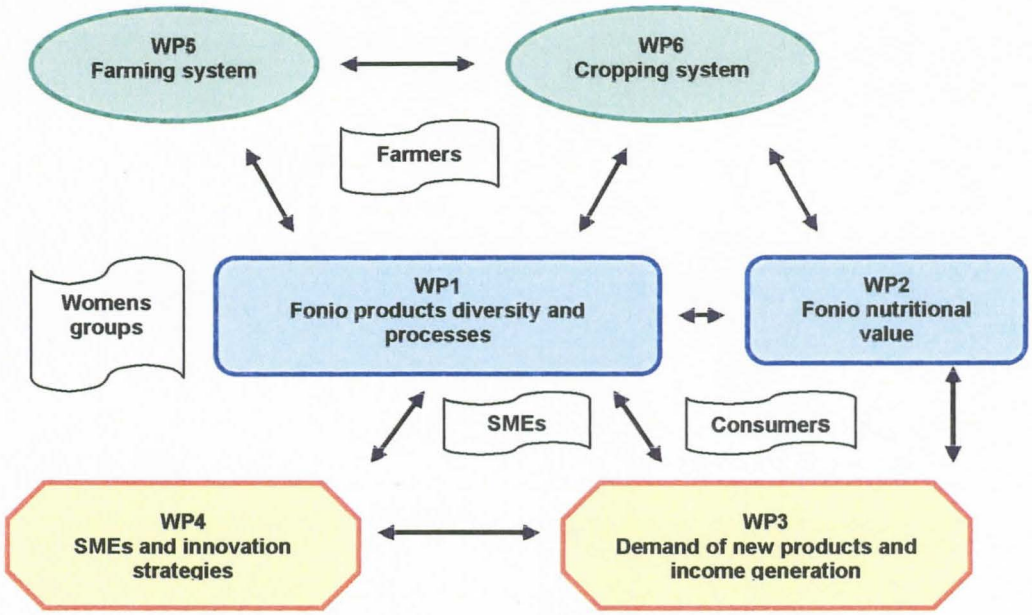


Fig. 1: Graphical presentation of FONIO work packages

Summary of the objectives, work performed, contractors involved and main achievements during the second reporting period.

WP1 is directed by Cirad (France) in close cooperation with IER (Mali). The main WP1 objective is to develop high quality fonio products with appropriate processes for local markets in West Africa and for exports.

During the second reporting period, the specific objectives of WP1 were:
1 - to focus on the development of a parboiling process for fonio by determining optimal conditions easily adaptable in small local enterprises to produce a good technological and organoleptic quality product for local or European consumers. The approach was to start at laboratory level on small quantities of grain, then to study in parallel the effect of some influent parameters under controlled local conditions before transferring the process in a small enterprise.
2 - to study fonio precooking at the small enterprises level
3 - to conduct drying tests in SMEs with processors -during the two seasons (humid, dry)- with the two solar and gas driers manufactured locally and start with the development of equipments for cooking
4 - to carry out analyses of many fonio ecotypes provided by WP5 and WP6, from Mali, Guinea and Burkina Faso for determination of their technological and cooking properties.

The major achievements of WP1 during the reporting period were:
1- The optimization of parboiling process at laboratory level for producing a parboiled fonio with good technological quality.
2 – The analysis of fonio precooking diagram in two small enterprises in Mali and Burkina Faso
3- The tests in local conditions during different seasons (hot and humid) of two driers manufactured in Mali -according to drawings elaborated last years- and comparison with two other gas and solar driers.
4- The analysis of different fonio ecotypes from Mali, Guinea and Burkina Faso and determination of their technological and cooking properties.

The main objective of **WP2** is to determine the nutritive value of fonio and fonio products and its contribution to nutrient intake and nutritional status. Within WP2, Wageningen University (division of Human Nutrition) in Holland is working closely together with WP1 and WP5. Activities within WP2 are carried out in close collaboration with the IER in Mali and the Université d'Abomey Calavi (Department of Food Science and Nutrition), Benin.

This objective will be achieved through the following specific objectives:

1 – To analyse the nutritional value of different fonio varieties, milled fonio and diverse fonio products (pre-cooked, parboiled).
2 – To determine the role of fonio in the dietary pattern.
3 – To determine the contribution of fonio to nutrient intake and nutritional status.
4 – To determine the bioavailability of iron from fonio-based diets.
5 – To determine the bioavailability of iron from low versus high phytate content fonio diets.

Activities of WP2 in 2007 mainly focussed on objective 1 (nutritional value of fonio and fonio products), objective 2 (the role of fonio in the dietary pattern) and objective 3 (contribution of fonio to nutrient intake and status).

Major achievements during the reporting period are:

- Samples of 12 fonio varieties are selected, sent to Wageningen and biochemical analysis was initiated.
- Standard processing methodology of fonio is developed in collaboration with WP1 and fonio products (parboiled and normal) were processed, sent to Wageningen and biochemical analysis was initiated.
- Preliminary results of the biochemical analysis of fonio varieties and products were presented on a poster during the 7th International Food Data Conference in Sao Paulo, Brazil, 22-24 October 2007.
- Desk review of existing Mali food composition table is finalised and table updated.
- A one-day food weighed record and sampling of duplicate portions among 36 women of reproductive age in Bamako is carried out and the samples were sent to Wageningen and biochemical analysis was initiated.
- Training of local research assistants on food consumption surveys was finalised.
- Food consumption survey (including two days 24-hour recall, frequency of fonio consumption questionnaire and qualitative dietary diversity questionnaire) among 108 women of reproductive age in Bamako was carried out and data analysis initiated.
- An attributes and pile sort study was carried out and a questionnaire on determination of factors predicting fonio consumption among women of reproductive age in Bamako was developed.
- Study on factors predicting fonio consumption among 108 women of reproductive age in Bamako carried out and report written.
- Official approval of the ethical committee for blood withdrawal was obtained.
- Nutritional status assessment among women of reproductive age in Bamako was carried out and data analysed.
- Venous blood withdrawal took place among women of reproductive age in Bamako; blood samples were sent to Wageningen and biochemical analysis was initiated.

WP3 led by Cirad concerns "demand for new products and its effects on income generation and distribution". WP3 contributes to the project since it provides information about the markets and the market chains of fonio products. WP3 includes first an analysis of the demand of fonio products in African cities as well as in European countries, and second an estimation of the impacts of the development of new products on the employment level and the income distribution in between stakeholders of the different market chains (old and "new"). WP3 has strong interactions with WP4 (dynamic of processing units) and WP1 (technological change) and to a less extent with WP5 (farming systems).

The main objectives of 2007 were:

- to analyse the data collected in 2006 in Mali concerning the demand for new products (Task 3.1). The results had to be presented and discussed with the main processors, before continuation.
- to study of the demand in Europe: protocol, survey and analysis (Task 3.2).
- to define and to launch activities concerning WP3&WP4 in Guinea which is specific compared to Mali, regarding new products and enterprises and to analyse first results of task 3.3. in Mali (2006 survey)
- to decide on which activity to focus for 2007 and 2008.

Major achievements during the reporting period are:
Task 3.1: Evaluation of the demand of new fonio products in African markets
- Consumer surveys implemented in 2006 in Bamako (Mali) were analysed (June 2007) and presented to a symposium (*106th seminar of the European Association of Agricultural Economists "Pro-poor development in low income countries: Food, agriculture, trade, and environment"*) at Montpellier, France, October 2007
- Presentation of the consumer survey results to processors and stakeholders at Bamako, June 2007
- Launch of a specific survey in Bamako (consumers of new products), November 2007

Task 3.2: Evaluation of the demand for fonio products and specific characteristics in European markets
- This activity was done and the results analysed. A survey about the acceptability of fonio by European consumers was implemented in June-December 2007 and two reports were produced (Ms. M. Lebrun)

Task 3.3: Impact on income generation and distribution of the development of new products
- Consumer and processor survey in Guinea, April 2007. Mission report. (N. Bricas)
- Processor survey in Mali (Bamako and Ségou), June 2007. Mission report. (Ms.S. Dury and J.F. Cruz)
- Analysis of data from stakeholders of the market chain in Guinea, June 2007. 4 reports. (Ms.M. Ndiaye)

WP4 is led by ENDA Graf (Senegal) and concerns "small scale enterprises and innovation in terms of products and processes" with the following specific objectives:
1 - Identification and typology of the SMEs involved in the process of fonio.
2 - Assessment of the different formal and informal relations between SME and their suppliers and their clients and of the internal organisation.
3 - Assessment of capacity and constraints of each type of SMEs to develop new products and process

During the reporting period the following specific objectives were given priority:
In Guinea:
- ✓ Identification, characterization and typology of fonio processing MSEs
- ✓ Survey on fonio product supplies and re-distribution networks (traditional, modern)
- ✓ Understanding the carriers of changes (players, process, impact, etc.)

In Mali:
- ✓ Completing the identification list of fonio MSEs in Mali to realize surveys in those enterprises (background, organization, operation, etc.).
- ✓ Characterizing and realizing the typology of Fonio MSEs
- ✓ Studying fonio product supply and distribution channels.
- ✓ Studying the relations between the various players
- ✓ Understanding how innovations (products, processes, techniques) have produced changes (description and analysis)
- ✓ Studying the various functions of MSEs and analyzing the logics, opportunities, constraints, strategies (innovations, product improvement, processes, etc.)

Major achievements of WP4 during the reporting period are:
About four surveys and exchange missions were carried out in the Year 2 by Enda Graf in collaboration with the project partners (IER/Ecofil, IRAG and Cirad).
A mission was realized in April in Guinea in collaboration with Ms M. Ndiaye and Y. Chaloub (IRAG), N. Bricas (Cirad) and J-F. Cruz (FONIO project coordinator). The mission, organized by T. A. Diallo (IRAG), project team leader in Guinea has allowed for meeting various types of actors, including producers, processors, traders, supportive institutions, the Ministry of Agriculture and the Environment. The mission participated in a broadcast program in Guinea on the issue of Fonio in West Africa.
Two missions were carried out in Mali. Mali presents a particular interest for WP4 and WP3. It is in that country that the highest number of fonio processing enterprises was recorded. Thus, the period going from May 21 to June 2, 2007 was an opportunity to enhance knowledge on MSEs in terms of organization and operation, their relationships, the employments created,.
A mission in Senegal (July 24 to August 3 2007) in the fonio production and marketing areas, and then in Dakar, where distribution enterprises are set up, allowed for better understanding the organization of the fonio market and its connections with Guinea and Mali.
The WP1 to WP4 meeting in October-November 2007 in Bamako allowed for stabilizing some data and launching a survey among about thirty fonio enterprises that were not surveyed previously.
Finally, Enda Graf participated in the project coordination meeting in Belgium, from the 24th to the 29th of November 2007 to share its findings with other partners.

WP5 led by Cirdes (Burkina Faso) and named "Opportunities of diversification and multiple uses of fonio in production systems", has five specific objectives:

1- Analysis of the range of fonio-based production systems and importance of fonio in the production system;
2 - Characterization of the importance of fonio in cropping systems;
3- Analysis of production and prospective strategies;
4 - Characterization of the assets and drawbacks of the socio-technical environment;
5 - Joint design of technical and organization innovations.

The year 2007 was devoted to the five objectives and the major achievements during the reporting period are the following:

Task 5.1: Analysis of the diversity of producers.

Data collected during the first year were analysed from November 2006 to January 2007. Then, the activity report was written to edit the deliverable D24 "Rapport sur la typologie des systèmes de production, base de données, identification des zones prioritaires d'intervention" in June 2007.

Task 5.2: Characterization of the place of fonio in the systems of production and its evolution

- Development of a collection of local varieties of fonio (November 2006 - January 2007)
- Development of monitoring forms (February 2007-March 2007)
- Monitoring of the fonio lands, and of the preparation of harvest (April 2007 - November 2007)
- Data analysis (December 2007)
- The final activity report is scheduled for February 2008:

Task 5.3: Analysis of the strategies of production and evolution pathways

Questionnaire drawing up on February 2007, survey implementation on May 2007, data Analysis on Aug/Sept. 2007 and report writing on Oct/Nov. 2007.

Task. 5.4: Characterization of the assets and constraints of the Socio-technical environment

Questionnaire drawing up on February 2007, survey implementation on June/July 2007, data Analysis on Aug/Sept. 2007 and report drafting on Oct/Nov. 2007.

Task. 5.5.: Co-designing of innovations

Setting up of the multi – areas tests and monitoring (April 2007-November 2007)

Common Activity WP5 and WP2: Test of fonio straw as foodstuff

Protocol drawing up (May 2007), production of fonio straw in station (June to October 2007) and feeding tests (from November 2007 to January 2008). Data Analysis and report writing are scheduled from February 2008.

Common Activity WP5 and WP6: Common Workshops

Participation in the WP6 meeting in Bamako to prepare the 2007 farming campaign (April 2007)
Organization of the WP5&6 "post-rainy season" meeting in Burkina Faso (October 2007)

WP6 is led by CRAW (Belgium) and involves IRAG, IER, CIRAD and CIRDES. The aim of WP6 is to improve the existing knowledge on fonio based cropping systems and to define ways to improve their productivity in phases with the market chain expectations. The objectives of the reporting period were:

- To compile, to analyse and to synthesize the results from the field campaign 2006 and to confirm them through the implementation of multi-local varieties comparison trials in two Guinean sites and two Malian sites, this in order to cover wider pedo-climatic conditions.
- To define Fonio response to abiotic factors such as soil nutrients content and to photoperiod variation, also to complete 2006 results.
- To characterise the 42 Fonio varieties collected, in 2006, in the different villages, from Guinea, Mali and Burkina Faso, followed up by the WP5. These varieties are characterised from a morphological, technological (in collaboration with the WP1) and biochemical point of view.
- Based on these results, to propose innovation schemes to the producers for the 2008 rainy season.

Major achievements during the reporting period are:

During the first semester of 2007, the partners focussed on the analysis of the results obtained in 2006 and on the preparation and implantation of the trials for the 2007 cropping season.

Variety trials highlighted the large variation existing amongst the different cultivars tested: 30 % to 40% between the worst and the better performances, respectively for the groups of the late and the early heading varieties. These results will be confirmed based on the results from the multi-local varieties comparison trial set up in 2007. This trial included 13 varieties in 4 sites : two in Guinea and two in Mali.

After the adaptation of different technologies, in order to measure thousand grains weight, to scan NIRS spectra of these grains, …., morphological and biochemical characterisation of these varieties, started in 2006, was continued in 2007 together with the characterisation of their technological value (WP1).

The analysis of 2006 results of the trials aiming to test fonio responses to photoperiod and its impact on biomass distribution has underlined the photoperiodism of this species with a flowering induction under shortening day length, the plants sown later during the rainy season had a shorter vegetative cycle and biomass production than the ones sown earlier. Nevertheless, each variety was characterized by its own intrinsic cycle length.

Exploratory fertilisation trials have led to the conclusions that N, P, K fertilisation could have a positive impact on fonio production even if these trials have also underlined the necessity to work on field with a low level of heterogeneity in terms of production potential to allow clear results interpretations. The three experimental sites were Bordo and Bareng, in Guinea, and Cinzana in Mali.

The exchanges with fonio producers underlined that both fertilization and weed control within fonio crops have to be elaborated in the context of the crops rotation scheme. Indeed, it had been underlined the difficulty to control weed invasion in a fonio crop set up after fallow. Control that is possible when this crop comes after a leguminous species profiting from the back effects of the rotation head (Sorghum, Millet, …) if they received manure. Such rotation scheme seems to maintain enough fertility for the fonio in order to reduce the pressure exerted by *Striga hermontica* occurring mainly on poor soils. This has to be taken into account during the evaluation of the interest of applying a light fertilization on this crop.

Cliché B. Dupuis (CRAW)

Fig. 2: Staff members of FONIO project inspecting experimental plots in Mali

Section 2 – Workpackage progress of the period

This section gives an overview of the actions carried out in the different workpackages during the reporting period. It was elaborated by gathering the specific reports sent by the workpackage and/or team leaders: Dr G. Fliedel (Cirad, France), Dr. I. Brouwer (WUR, The Netherlands), Dr. S. Dury (Cirad-France), Dr. D. Guindo (IER, Mali), T.A. Diallo (IRAG, Guinea), B. Touré (ENDA, Senegal), Dr. E. Vall (Cirdes, Burkina), Dr. D. Stilmant (CRAW, Belgium).

2.1. Work package 1 - Diversification of fonio products for niche export markets and local markets

Responsible scientist: Dr. Geneviève Fliedel - Cirad (France)
Other participating contractors: IER (Mali) and IRAG (Guinea)

Participant n°	1	4	5
Organisation name	Cirad	IER	IRAG
Country	France	Mali	Guinea
Staff	**Ms G. Fliedel** J. Grabulos M.Rivier C. Marouzé J.F. Cruz	**D. Dramé** Ms C. S. Sidibé Ms B.F. Guindo M. Diarra K. Tangara	Ms M. Ndiaye

Workpackage objectives

Work objectives of reporting period were the followings:
- To adapt to fonio grain a parboiling process usually used on rice, by studying the effect of some influent parameters on technological and cooking properties of parboiled grain.
- To study fonio precooking at the small enterprises level in Mali and Burkina Faso
- To conduct drying tests with two driers (a counter current cross-flow gas drier and a greenhouse ventilated solar drier), each one built locally and set up in a small different enterprise, through various seasons in the year.
- To analyse technological and cooking properties of different fonio ecotypes from Mali, Guinea and Burkina Faso.

Progress towards objectives – tasks worked on and achievements

2.1.1. Precising quality criteria of milled and cooked fonio and laboratory protocols (task 1.1.)

During the first year of the project, the identification of quality criteria of milled and cooked fonio was carried out in Mali and laboratory protocols on assessment of fonio quality were improved.
This activity achieved in Mali was supposed to be partly conducted in Guinea during the second year of the project if local conditions would be safety. It was not the case and it will be only during the third year of the project that we intend to start this activity through sensory tests on organoleptic characteristics of cooked fonio depending on cooking way and on local varieties.
Sensory tests will be developed in IER, Mali during also the third year of the project on the local ecotypes provided from WP5 and analyzed in task 1.4. For each variety, organoleptic properties will be identified and will be related to milling, cooking properties and physico chemical characteristics of grains presently available.
A protocol to measure some physical characteristics such as endosperm texture or grain hardness will be also developed in Cirad.

2.1.2. Producing precooked and parboiled fonio products with constant and improved technological, organoleptic and nutritional qualities (task 1.2.)

The objective of task 1.2 is
- to develop parboiled fonio products for local markets or for export by adapting to fonio a process already traditionally used for rice
- to analyse precooked fonio products for local markets or for export and to improve precooking technology at SME level.

2.1.2.1. Fonio parboiling in Cirad laboratory

The advantages of such a process for rice are the improvement of : 1/ milling yield with a reduction of brokens, 2/ cooking quality and in particular a decreasing of cooked rice stickiness and 3/ nutritive value of milled grain. Meanwhile, parboiled milled grains get a darker colour.

The different steps for reaching this objective were to study in Cirad laboratory the effect of influent parameters of parboiling process on fonio quality product, then defining the optimum fonio diagram at laboratory level in Cirad and also under controlled local conditions in IER, before transferring it in a small local enterprise.

The methodological approach was to:
- establish a parboiling laboratory process with equipments adapted to fonio grain size and to small quantities of grains
- choose and adopt analytical methods for assessing parboiled product quality
- study paddy grain behaviour during soaking in water at different temperatures
- determine the minimum grain water content for starch gelatinisation
- start with preliminary experiments for defining minimum and maximum limits for each factor studied
- select factors to be studied and define the others
- choose an experimental design to reduce the number of experiments

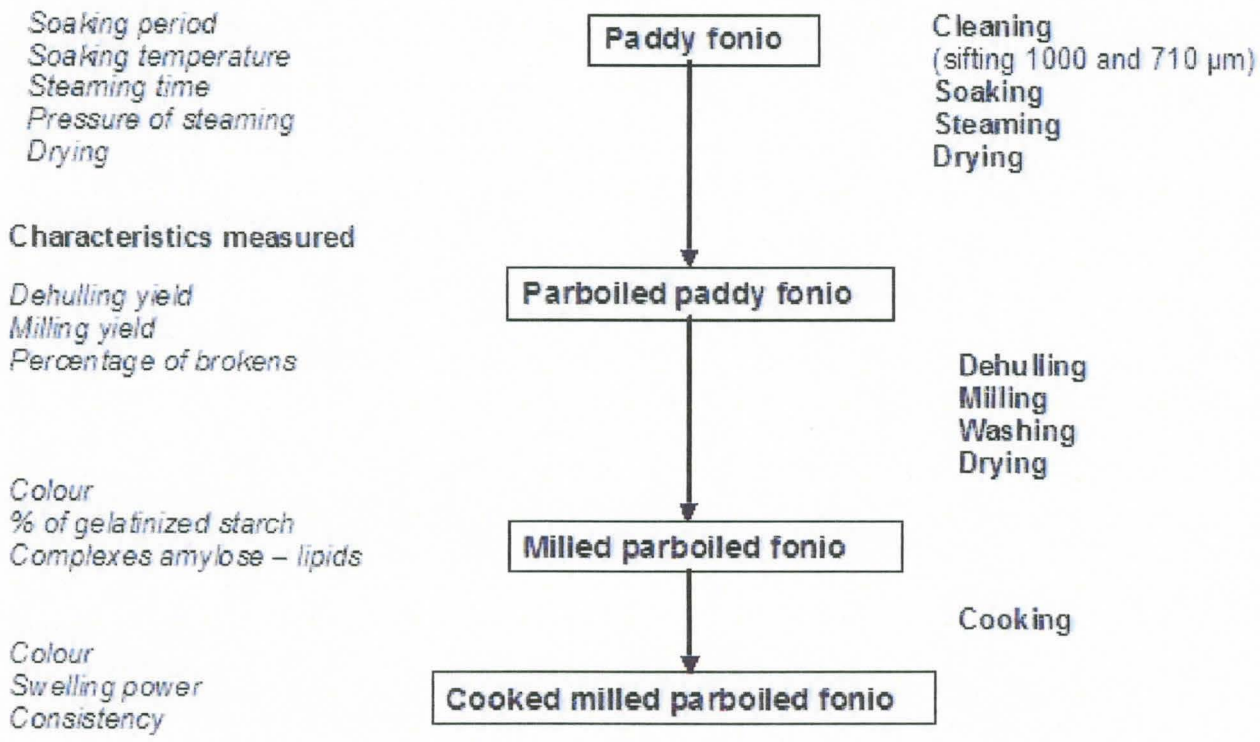
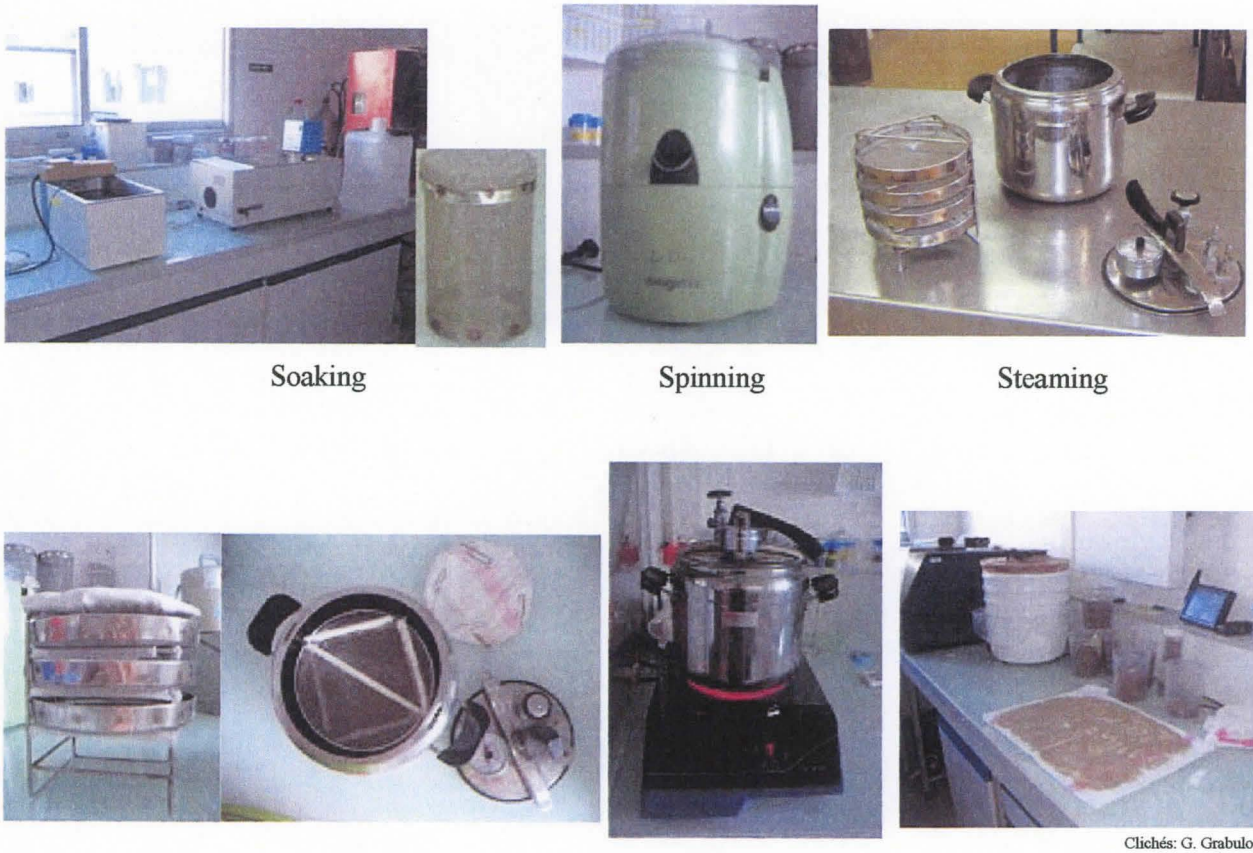


Fig.3. Diagram of fonio parboiling in Cirad laboratory

Diagram of fonio parboiling

Parboiling of fonio paddy grain requires several successive steps:
- *Cleaning*: fonio paddy grain was cleaned (per batch of 100 g of grain) through an Alpine air jet sifter by using a 1000 µm mesh sieve to remove large particles (other grains, stones, straw) and a 710 µm mesh sieve to remove fine particles (dust, immature grains).
- *Soaking*: fonio paddy grain was soaked at different temperatures during various periods depending of tests. 70 g of paddy grains were introduced in a wire mesh box totally immersed in the soaking water bath under continuous stirring.
- *Spinning*: to remove residual water on grain surface, soaked paddy grain was centrifuged during 2 min in an household machine that turns at 2000 rd/min. The inside basket (16cm diameter) containing the grains was adapted to that use by protecting the grating bottom with a rigid plastic plate and the perforated walls with a cotton tulle.
- *Steaming*: soaked paddy grains were steamed under or not pressure in a laboratory autoclave of 20 cm of diameter and 10 l of capacity heated by a hotplate with 500 ml of water in the bottom. They were displayed on four metallic superposed screens (about 30 g of grain per screen, 710 µm openings) of a support adapted to this pressure cooker. Each support metallic tube and a cover put on the upper screen were protected by a cotton tissue to avoid that condensation drops fall down and damage paddy grains during steaming.
- *Drying*: after steaming, paddy grain was dried in a laboratory drier equipped with a ventilator and placed in an air conditioned room (20°C, 65% RH). After about 18h, fonio grain water content was of 13-14% w.b.

Parboiled paddy grain was then dehulled, milled, washed, dried and cooked according the laboratory standardized protocols mentioned in task 1.4.



Soaking Spinning Steaming

Steaming Drying

Clichés: G. Grabulos (Cirad)

Fig.4. Different steps of fonio parboiling in laboratory

Analytical methods

Quality of parboiled fonio was assessed at each step of the process and the characteristics measured were the followings:

- on parboiled paddy grain: dehulling yield, then milling yield and percentage of brokens (see task 1.4)
- on milled parboiled fonio: colour, percentage of gelatinized starch, formation of amylose-lipid complexes
- on cooked milled parboiled fonio: colour, swelling power and consistency (see task 1.4)

Colour of milled and cooked parboiled grain was measured with a Minolta chromameter by using L, a, b system. L represents clearness and a, b chromaticity: +a goes to red, -a to green, +b to yellow and –b to blue; +L goes to white and –L to black.

Fig.5. Minolta chromameter and system L, a, b

Percentage of gelatinized starch and formation of amylose-lipid complexes were measured by using a Differential Scanning Calorimeter. This equipment (Perkin Limer DSC7) using hermetic stainless steel pans, measures enthalpy differences between a sample and a reference submitted to linear heating and cooling cycles. The pan containing the sample (9-10 mg of ground fonio milled grain –parboiled or not- with 45µl of pure water) and the pan containing the reference (45 µl of pure water) were heated from 25°C to 160°C at 10°C/min.

An enthalpy change was observed at about 80-85°C: it corresponds to the gelatinization of fonio starch not already gelatinized during parboiling. By comparing its area ΔH (J/g d.b.) to that of the enthalpy change observed on non parboiled milled fonio, we could determine the percentage of gelatinized starch during parboiling.

A second enthalpy change was observed around 110°C: it corresponds to the melting of amylose-lipid complexes developed during parboiling. The presence of this endotherm and the importance of its area are indicative of the non sticky aspect of parboiled grain.

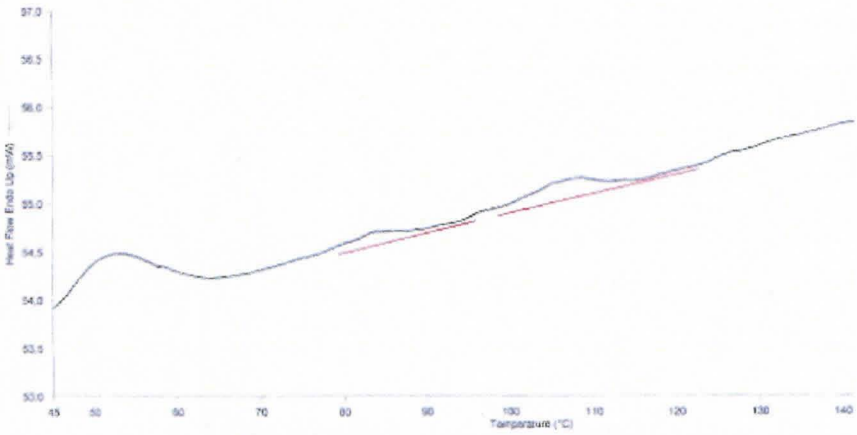


Fig.6. Enthalpy change of a parboiled fonio

Influent factors

The main parameters in the parboiling process that could have an effect on the quality of fonio parboiled grain should be the followings:
- *Soaking period*
- *Soaking temperature*
- *Steaming time*
- *Pressure of steaming*
- *Drying temperature and period*

To study the effect of influent parameters of parboiling process on fonio quality product and define the optimum fonio diagram at laboratory level, an experimental design was used to reduce the number of experiments. Previously, preliminary experiments were conducted to precise the measurement range and thus the study limits for each parameter.

Main results

Paddy grain behaviour during soaking in water at different temperatures

Kinetics of water absorption by fonio paddy grains during various soaking periods have been carried out at 25, 30, 35 and 40°C, temperatures chosen under fonio starch gelatinisation temperature (75.7°C) and close to ambient temperatures in West Africa depending of seasons or countries. Samples of 2.5 g soaked grain were removed out of water at shorter intervals during the first part of the soaking period and then at longer and longer intervals, following an exponential function with a 0.2 step and a 9 hour period. They were then centrifuged during 1 min to remove residual water before a complete dehydration in an oven at 100°C for determining paddy grain water content at each interval.
All the water absorption curves followed a logarithmic profile. They increased rapidly during the first soaking minutes before reaching a plateau at about 38 % w.b. of grain water content. *The higher the temperature, the faster the water absorption by paddy grain.*

These kinetics have been useful to predict the soaking period for reaching a paddy grain water content at a given water temperature: for instance, it should be necessary to soak the grain during a minimum of 2h36 at 30°C for it to reach a water content of 30% w.b., at 25°C, 3h50 to reach 31.2% water content and at 40°C, 1h42 to reach 30.9% water content.

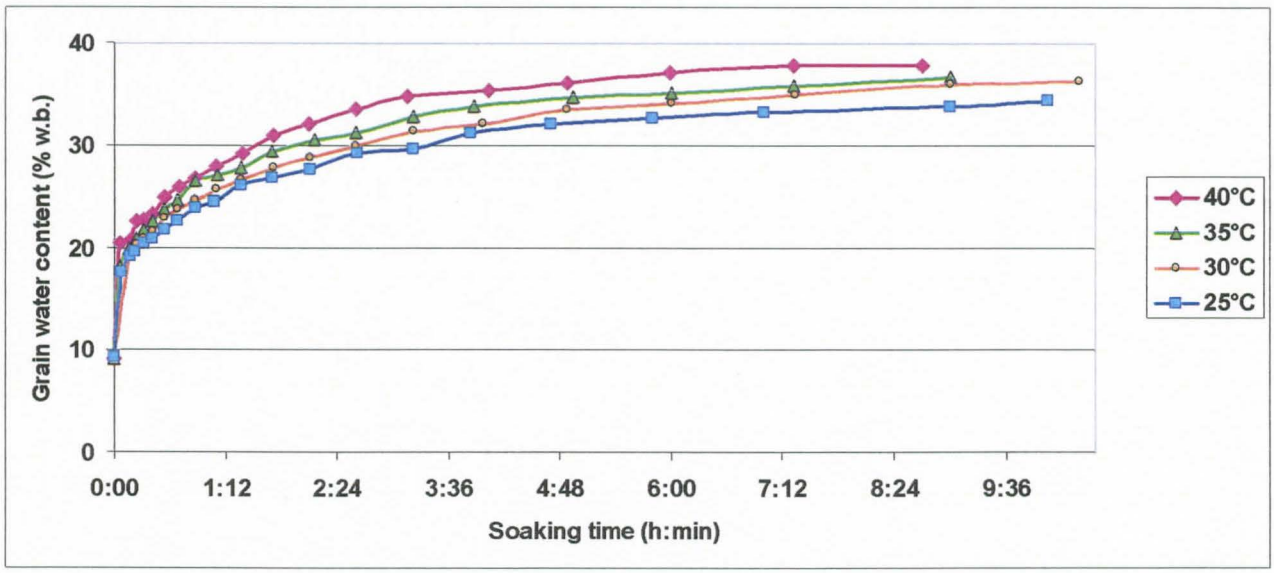


Fig.7. Kinetics of water absorption by fonio paddy grains at different temperatures

Determination of minimum grain water content for starch gelatinisation

To determine the minimum water content of paddy grain during soaking to get a starch gelatinization during steaming, several samples of 30 mg ground milled grain were added with increasing quantity of pure water -to cover a water content range from 10 to 45 %- and were analyzed by DSC Differential Scanning Calorimetry. A slight enthalpy change appeared at about 25% w.b. water content. Its area ΔH (J/g d.b.) increased with quantity of water added and, compared to that obtained with water in excess (45 µl), the percentage of gelatinized starch at each grain water content was determined. At 25% water content, the percentage of gelatinized starch is low, 1 % only, increased to 9% at 38% w.b. and climbed to 100 % at 50-55% w.b.

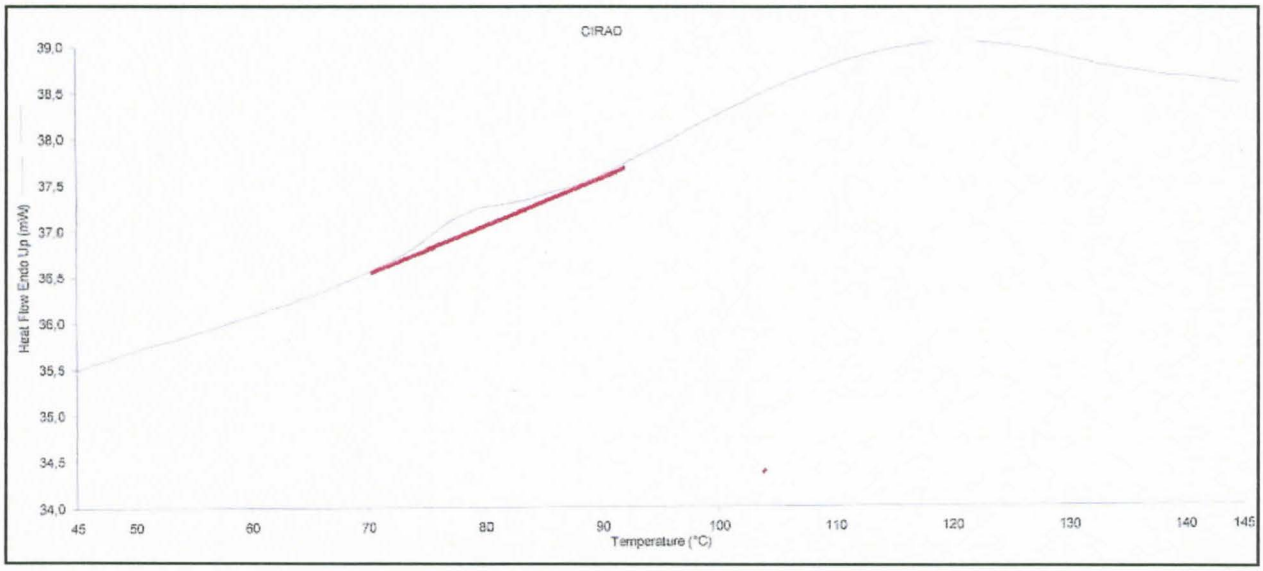


Fig.8. Starch gelatinization with minimum of water

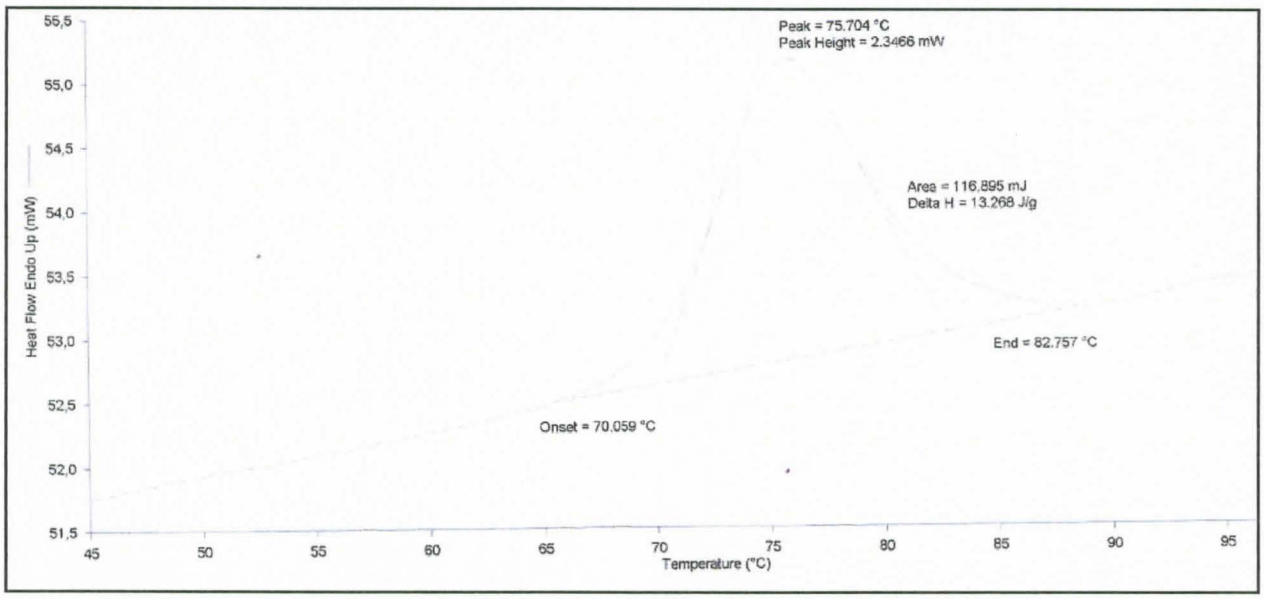


Fig.9. Starch gelatinization with water in excess

These preliminary experiments leaded us to precise study range for soaking temperature and period. To limit the number of experiments, soaking temperature was fixed at 30°C, a mean value in West Africa. Soaking periods were studied between 1h and 7 h, 1 h corresponding to a 25 % water content for soaked grain with a beginning of starch gelatinization and 7 h corresponding to a 35 % water content just before

the 38 % plateau, during a convenient period for a laboratory day and maintaining paddy grains intact in warm water under stirring (longer periods seemed to open paddy grains).

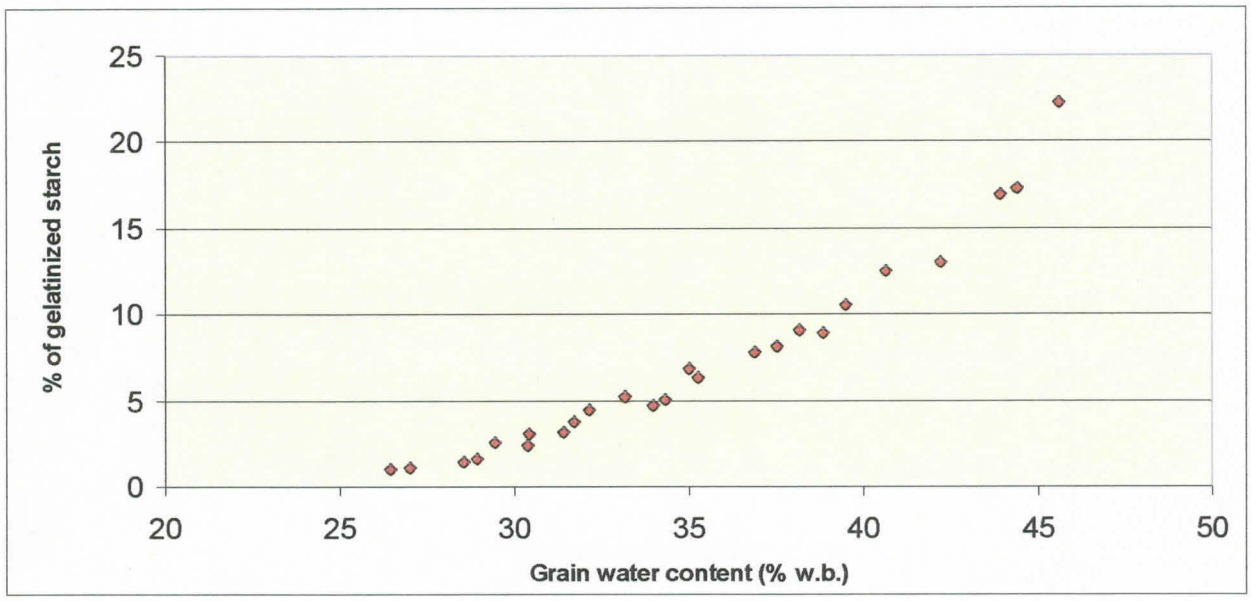


Fig.10. Percentage of gelatinization of fonio starch

Behaviour of fonio grain during parboiling

To determine study range for the two factors, steaming period and pressure, before starting with experiments within an experimental design, other preliminary experiments were conducted and parboiled grain observed with a binocular. The objective was to test different steaming pressure (from 0 to 1 bar) during shorter and longer periods (from 5 to 30 min) with lower and higher grain humidity (25 to 35 % w.b.) and see from what pressure the grain was damaged. Over than 0.8 bars, the paddy grain opened systematically, even during shorter period (5 min) and lower grain water content (24 %). With 0.4 bars during 20 min, some grains opened, over were dehusked, but most of them remained intact even at 34 % water content.

Several of these parboiled samples were analyzed by DSC to assess gelatinization degree and formation of amylose-lipid complexes in order to define the limits of the hydrothermic treatment. After 10 min steaming with no pressure (0 bar) of a 30 % water content grain, a partial starch gelatinization (37 %) was observed but no melting trace of complexes formed during parboiling. For a grain at 35 % water content, parboiled at 0.4 bars during 20 min, starch was gelatinized at 100% and amylose-lipid complexes were developed. A compromise was retained with interpretable results for a study range of 0 to 0.4 bars for pressure and 10 to 26 min for steaming period.

Beside water temperature maintained at 30°C for soaking within the experimental design, water pH was chosen to be constant (pH of distilled water) and drying conditions controlled: in a drier equipped with a ventilator and placed in a conditioned room at 20°C, 65 % RH.

350 g of fonio were parboiled per experiment.

Doehlert experimental design and statistical analysis

After defining study limits of some influent factors and defining others, optimization of parboiling conditions at laboratory level was carried out on the same fonio variety *Tamatioi* from Segou, Mali, using response surface methodology. A Doehlert experimental design was performed for determining the experimental conditions that provide the highest responses. This design was built with three factors at 7, 5, and 3 levels respectively, and was composed of 15 runs, including three replicates at the central point. The three independent factors chosen were soaking time (from 1 to 7 h), steaming time (10 to 26 min) and steaming pressure (0 to 0.4 bars), soaking temperature being fixed at 30°C. The proposed model to which the experimental data were fitted is a second-order polynomial model.

The following equation was used:

$$Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_{12}X_1X_2 + a_{13}X_1X_3 + a_{23}X_2X_3 + a_{11}X_{12} + a_{22}X_{22} + a_{33}X_{32}$$

where Y is a technological response, a_i are the regression coefficients (a_i: linear effect of factors, a_{ii}: quadratic effect of factors an a_{ij}: interactions of factors), and X_1, X_2, and X_3 are the experimental factors.

Doehlert matrix with real values calculated from coded values shows the different experiments carried out.

Experiment	Soaking time (h)		Steaming pressure (bars)		Steaming time (min)	
1	02:38:45	0 *	0,2	0 *	26	1 *
2	02:38:45	0	0,2	0	10	-1
3	06:08:40	0,866	0,2	0	22	0,5
4	01:08:21	-0,866	0,2	0	14	-0,5
5	01:08:21	-0,866	0,2	0	22	0,5
6	06:08:40	0,866	0,2	0	14	-0,5
7	03:30:17	0,289	0,4	0,816	22	0,5
8	01:59:50	-0,289	0,0	-0,816	14	-0,5
9	01:59:50	-0,289	0,0	-0,816	22	0,5
10	04:38:18	0,577	0,0	-0,816	18	0
11	03:30:17	0,289	0,4	0,816	14	-0,5
12	01:30:33	-0,577	0,4	0,816	18	0
13	02:38:45	0	0,2	0	18	0
14	02:38:45	0	0,2	0	18	0
15	02:38:45	0	0,2	0	18	0

*: values in the right part of each column are the corresponding coordinates in a normalized space

Table1. Doehlert experimental design for three variables

The weight of each parboiling factor and the weight of interactions between them were determined for each response with Statistica® through statistical analysis of the experimental design. An analysis of variance with a Fisher test was run on each coefficient to determine p-value and find the significance of the linear, quadratic and interaction terms in the response surface models ($\alpha = 0.05$). The models built from all the runs of the experimental design as a function of soaking time, steaming pressure and steaming time are summarized for each response in Table.

All the R^2 values were between 0.95 and 0.99 except for two responses (consistency: 0.87 and percentage of brokens: 0.89) indicating a good suitability between the model and experimental data. Standard deviation to the central point showed lower values, representative of a good repeatability and reproducibility of runs and analyses.

- *Total milling yield*

Total milling yields of parboiled fonio were all higher than the total milling yield of non parboiled fonio: respectively from 76.5 to 79.1 % compared to 71,7 %.
The quadratic effect of steaming time was positive and highly significant indicating that total milling yield presented a minimum in the experimental domain considered.
Interactions between steaming pressure and soaking time were significant. Their negative values indicate that higher milling yields were obtained either with longer soaking times and lower pressure or with higher pressure and shorter soaking times.

- *Colour of milled and cooked parboiled grain*

Parboiling affected milled grain colour which became darker. Clearness of parboiled grain was lower than that of non parboiled grain (from 52.2 to 62.6 compared to 71.1). It was significantly and negatively influenced by soaking time and in a lesser extent by steaming time. The clearer the grain, the shorter the

soaking time and the shorter the steaming time. Response surface curve confirmed that higher L values were obtained with shorter time of soaking and steaming. A same predominance of soaking and steaming time main effects was observed on a values, but here with a positive trend: the grain became more and more red by prolonging soaking or steaming period. However, a maximum was found for the central points because of the negative quadratic term of steaming time and pressure.

After cooking, parboiled grain became lighter and less red or yellow than milled parboiled grain. It became closer to cooked raw grain but remained slightly darker and redder than it (L: from 61.3 to 65.5 compared to 70.6 ; a : from 0.13 to 1.09 compared to 0.02 for non parboiled grain). Soaking time and in a lesser extent steaming time had a highly significant and negative effect on clearness and a significant positive effect on chromaticity a and b of cooked parboiled grain. The effect of these two factors had a repercussion on fonio grain colour even after cooking. Soaking time had a main negative effect on clearness indicating a decrease of clearness with a longer soaking period. The two other factors (steaming time and pressure) showed predominant quadratic effects, positive on L clearness and negative on a and b chromaticity indicating a minimum for L and a maximum for a and b at medium values of factors. Quadratic terms of soaking time were slightly predominant compared to linear terms for a and b chromaticity indicating a maximum at central points.

- *Gelatinized starch*

Enthalpy change of starch gelatinization which appeared for parboiled grain between 80.3 and 84.3°C showed areas between 0.13 and 4.84 J/g (d.b.), corresponding to a percentage of gelatinized starch of 63.6 to 99.1 % during parboiling. This variable was highly and negatively affected by soaking time and steaming pressure with a linear effect of these factors. This means that starch was gelatinized in larger quantity with a longer soaking time and a higher steaming pressure. A negative interaction between soaking time and steaming pressure indicated that higher percentages of gelatinized starch could be obtained with longer soaking time and lower steaming pressure or with shorter time and higher steaming pressure.

- *Amylose-lipid complexes:*

Amylose-lipid complexes could form during parboiling, depending on parboiling conditions. Their presence and their importance (area of the enthalpy change), identified during melting at around 110°C, is a quality trait for parboiled grain. This characteristic was highly significantly influenced by steaming pressure (linear and positive quadratic effect) but also by steaming time and soaking time. More precisely, the response increased as the three factors increased. Significant and positive interactions between soaking time and steaming time were observed indicating that formation of complexes was favoured with a long steaming time preceded by a long soaking time or a short steaming time preceded with a short soaking period. The response surface curve showed that it could be possible to form amylose-lipid complexes during parboiling with shorter steaming periods by using higher pressures and vice versa with no steaming pressure –as usually found in local conditions in West Africa- but with longer steaming periods.

- *Swelling power:*

Parboiled fonio swelled more than non parboiled fonio during cooking, what is not observed with rice. This property, very important for local consumers, was particularly influenced by steaming pressure (positive linear and quadratic effect) and in a lesser extent by soaking time (positive quadratic effect). These quadratic effects indicate a minimum value for centred points. Higher swelling powers were found for fonio grain parboiled with no pressure and longer steaming time or the reverse and for grain parboiled with short soaking time and long steaming time, as shown with response surface curves.

	Paddy grain	Milled grain			Ground milled grain		Cooked grain				
	Total milling yield (%)	Colour			ΔH gelatinized starch (J/g d.b.)	ΔH complexes amylose-lipid (J/g d.b.)	Swelling power (g of water absorbed, % d.b.)	Consistency (N)	Colour		
		L	a	b					L	a	b
Non parboiled fonio	71.7	71.1	0.86	12.6	13.3	0	222.5	20.9	70.6	0.02	9.51
Parboiled minimum	76.5	52.2	2.15	15.6	0.13	0	226.1	21.2	61.3	0.13	10.92
Parboiled maximum	79.1	62.6	3.39	18.0	4.84	1.15	243.0	26.7	65.5	1.09	12.71
Standard deviation to the central point	0.22	0.66	0.11	0.16	0.52	0.11	6.75	0.84	0.36	0.16	0.31
R^2	0.95	0.97	0.96	0.89	0.99	0.97	0.90	0.87	0.99	0.98	0.98
Constant	77.1	55.8	3.06	17.6	1.99	0.36	229,2	26.6	62.5	1.02	12.7
Main effects											
a_1 (soaking time)	- 0.54 *	- 4.39 ****	0.49 ***	0.54 *	- 2.39 ****	0.32 **	0.92	0.43	- 1.67 ****	0.36 ***	0.52 ***
a_2 (steaming pressure)	- 0.37 *	- 0.87	- 0.04	0.04	- 1.69 ****	0.48 ***	3.64 *	0.90	- 0.17	0.09	- 0.04
a_3 (steaming time)	- 0.43 *	- 1.92 **	0.29 **	0.62 *	- 0.50 *	0.35 **	3.18	- 0.19	- 1.02 ***	0.21 **	0.47 ***
Quadratic terms											
a_{11} (soaking time)^2	0.89 *	0.98	- 0.25	- 0.96 *	0.66	0.02	8.88 *	- 1.61	0.52	- 0.40 **	- 0.73 ***
a_{22} (steaming pressure)^2	0.34	0.33	- 0.25 *	- 0.12	- 0.01	0.40 *	9.54 **	- 2.56 *	1.26 ***	- 0.50 ***	- 0.91 ***
a_{33} (steaming time)^2	1.58 ***	0.68	- 0.33 *	- 0.54	- 0.02	0.08	1.74	- 0.66	1.45 ***	- 0.53 ***	- 1.08 ***
Interactions											
a_{12} (so. time x st. pressure)	- 1.07 *	2.02	- 0.02	0.09	1.27 *	- 0.09	0.17	2.46	0.18	- 0.07	0.07
a_{13} (so. time x st. time)	0.31	1.52	- 0.05	- 0.65	0.12	0.40 *	- 0.97	0.55	0.38	- 0.03	- 0.50 *
a_{23} (st. pressure x st. time)	- 0.74	0.26	0.17	- 0.36	0.18	- 0.28	- 5.04	- 3.66 *	0.17	- 0.05	- 0.37

**** : p value < 0.001 % ; *** : p value < 0.01 % ; ** : p value < 0.1 % ; * : p value < 0.5

Table 2. Regression coefficients of the equation for each technological response

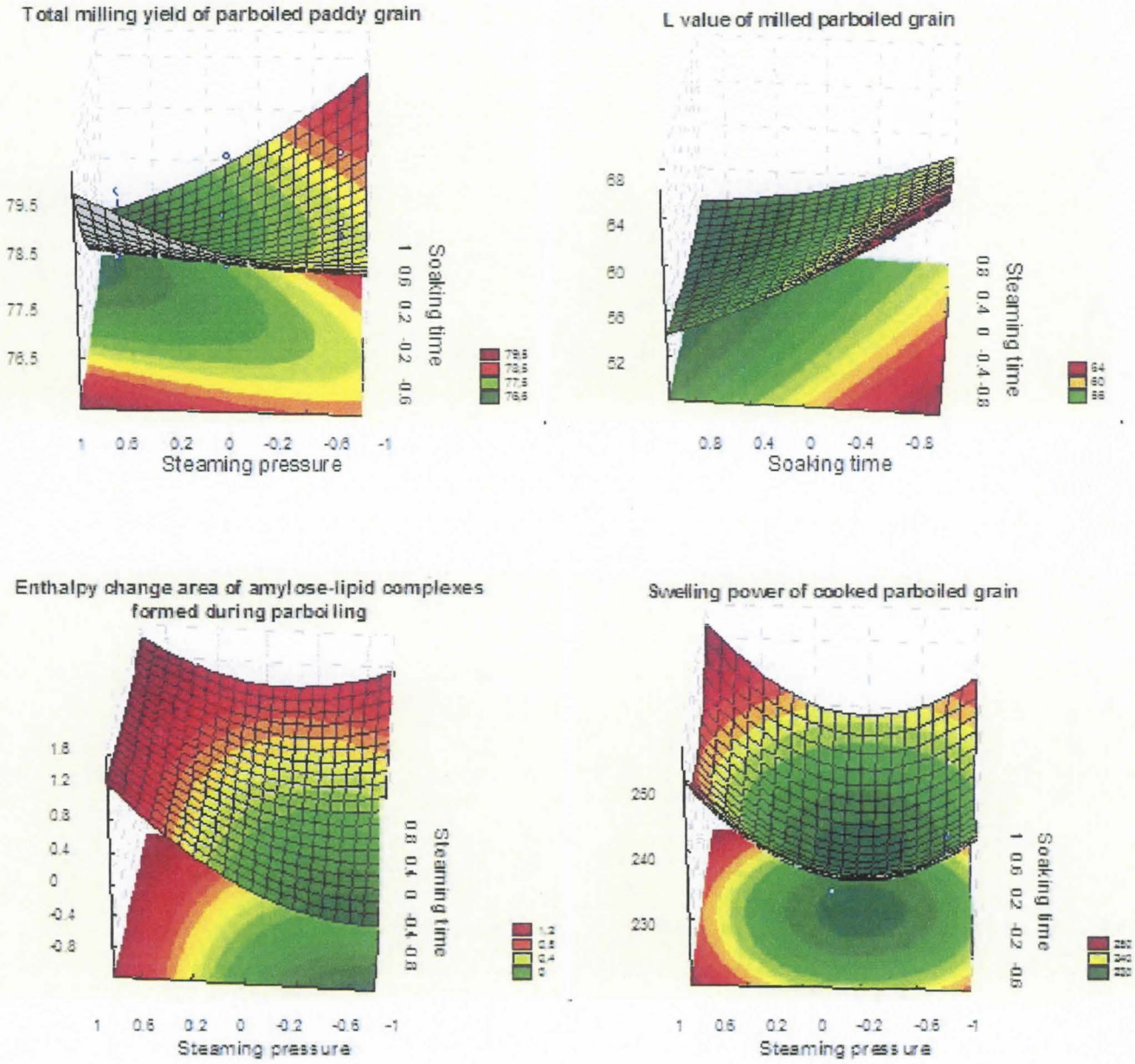


Fig.11. Response surface curves (effect of soaking time, steaming time and/or pressure on four technological responses)

Optimisation of parboiling conditions

Parboiling was supposed to improve fonio technological quality, mainly total milling yield, swelling power and non sticky aspect. However, optimisation of each response was not obtained in the same conditions and a compromise had to be found. A desirability function was used with Statistica® to calculate simultaneous numerical optimisation of multiple responses and range from 0 to 1 (least to most desirable respectively). Optimal parboiling conditions were calculated by including a desirability of five variables: higher milling yield, lower percentage of brokens, softer consistency, higher swelling power and higher enthalpy change of amylose-lipid complexes melting. The desirability profile answered at 94 % to our technological quality demand.

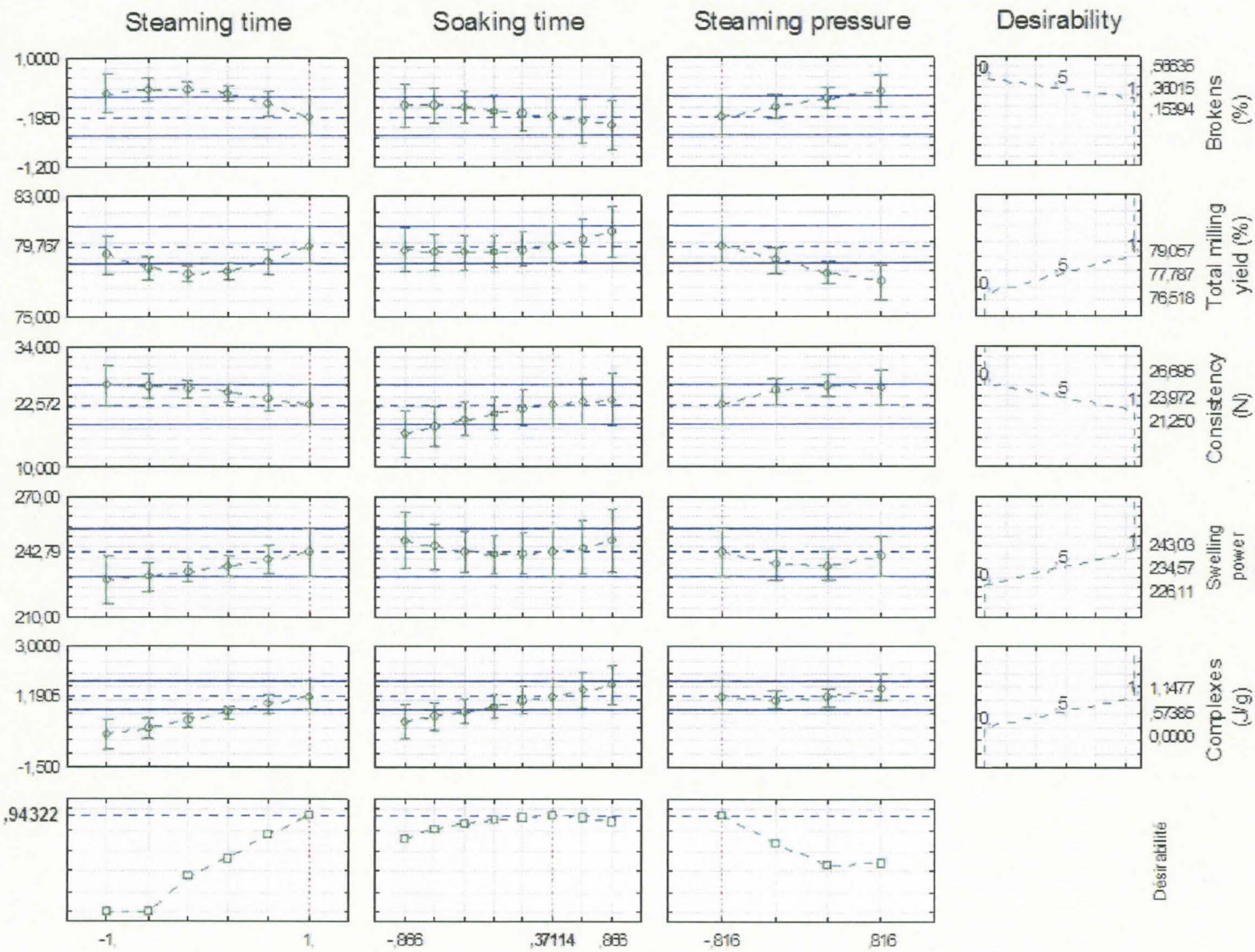


Fig.12. Desirability function of five variables

Optimal parboiling conditions could be obtained in the following experimental conditions:

	Optimal coded value	Optimal parboiling conditions
Soaking time	0.37	3 h 47
Steaming pressure	- 0.82	0 bar
Steaming time	1.00	26 min

Table3. Optimization of the three factors to get a good technological parboiled grain

By using the second-order polynomial model and R2 value, it could be possible to predict, for each response, experimental data in the optimal parboiling conditions. These estimated data appeared consistent for the main variables. It should be necessary to conduct an experiment in these optimal conditions to check the prediction of our experimental design.

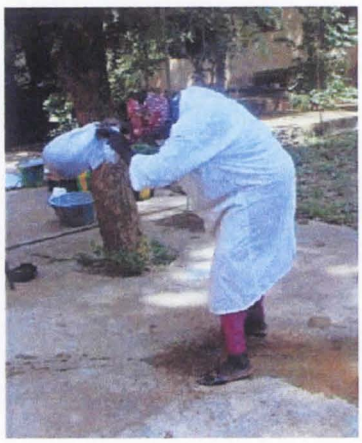
Note: This optimization did not include a desirability on clear grain colour (high L value and low a, b chromaticity values) since this criteria did not seem important for export (WP3 results). But for local populations who are attached to a white grain, it should be necessary to found a compromise, notably by reducing soaking time and in a lesser extent steaming time.

2.1.2.2. Parboiling tests in IER controlled conditions

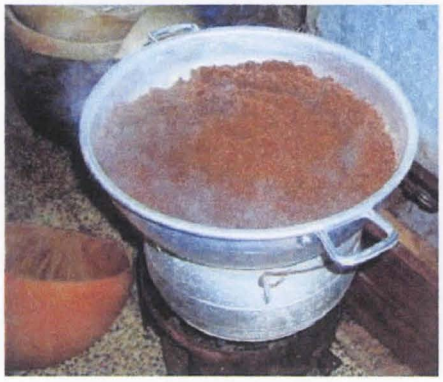
Parboiling tests were conducted in parallel by IER on larger quantities of grain (5 kg) to complete laboratory experiments in Cirad. The effect of soaking time (all night long and from 2 to 6h) but also soaking water pH (6-7 and 3) and temperature (50-60°C, 25-30°C) on paddy grain water content and milled grain colour were studied with three different varieties (from Segou region, Mali). They are still in progress.

Cleaning by washing

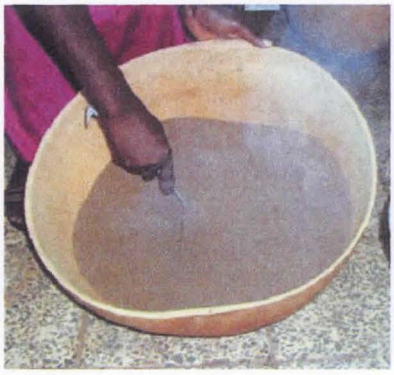
draining



spinning



Parboiling



cooling

drying

Clichés: G. Fliedel (Cirad)

Fig.13. Parboiling experiments in IER

The first results indicated that adding citric acid at different concentrations to decrease soaking water pH from 6-7 to 3, had a slight effect on grain colour: for instance, Tama variety soaked during 2h at 45-55°C with and without addition of 2g/l of citric acid (pH 3) got grains after steaming and drying slightly clearer when adding acid (respectively 54.3 and 51.9 for L value; 1.9 and 2.6 for a value; 20.4 and 20.0 for b value). But this difference did not appear so important to ask processors to reduce pH of soaking water in view of lightening parboiled milled grain colour.

Other result: it did not appear necessary to soak the grain all night long even at low temperature (25-30°C) to reach a sufficient water content (32-35 % w.b.) for parboiling. 4-5 h should be enough even if it could be more convenient for a processor to let the grain all night long in water and start steaming in the morning. A too long soaking could affect grain colour, as seen previously with laboratory results. Heterogeneity in the steamed product was noticed: the grains in the bottom of the steam cooker were more cooked but darker than the grains in the upper part.

2.1.2.3. Identification of existing processes and equipments

Fonio precooking at SME level in Mali and Burkina Faso

An identification phase of precooking operation was carried out at the level of two fonio processing SMEs in Bamako and Ouagadougou. This experiment was completed during an expert mission realized by Cirad (Michel Rivier and Jean-François Cruz[1]) in Mali and Burkina Faso from the 6 to 13 March, 2007.

In Mali the fonio whitening and precooking diagram was identified as following

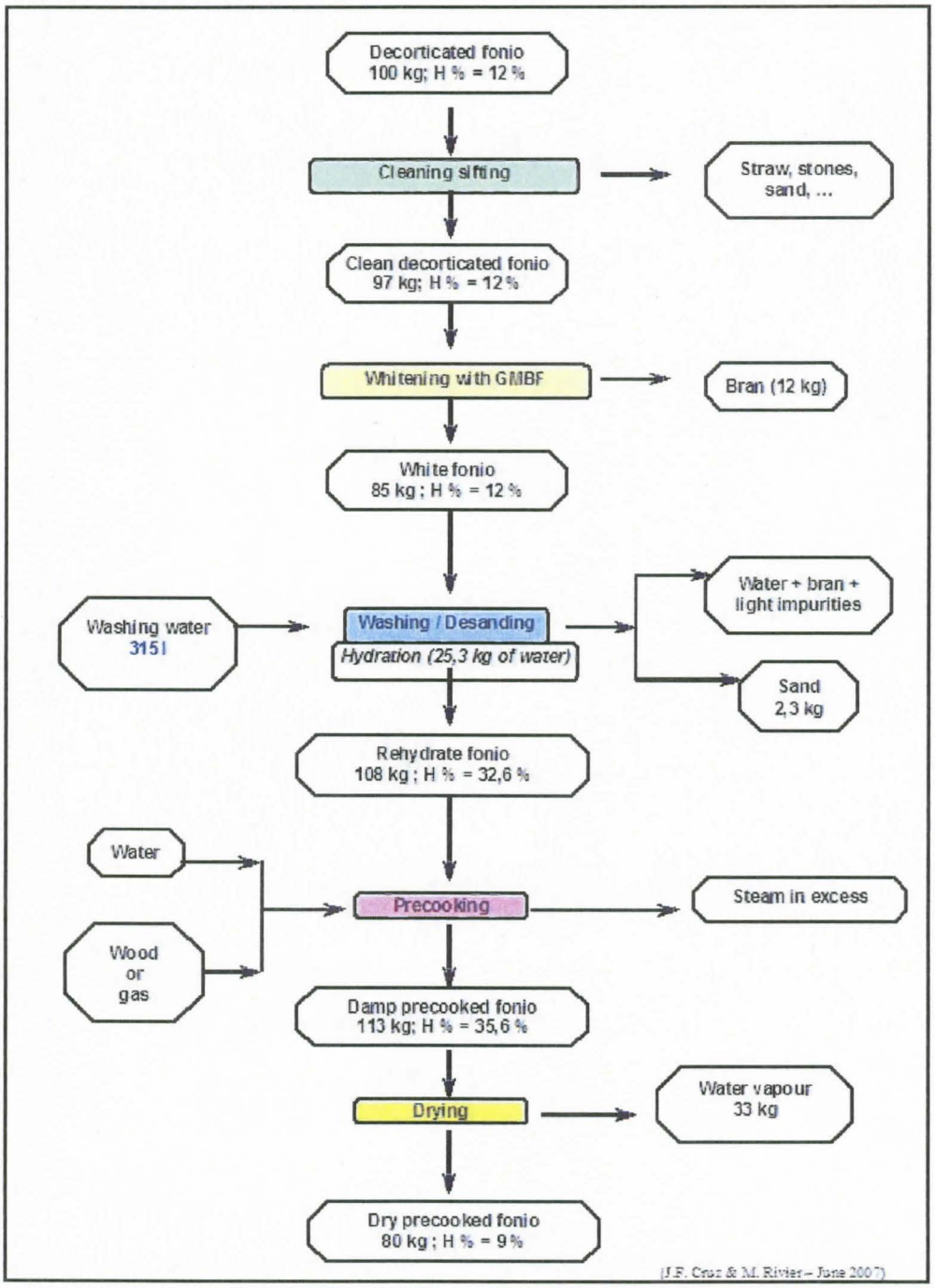
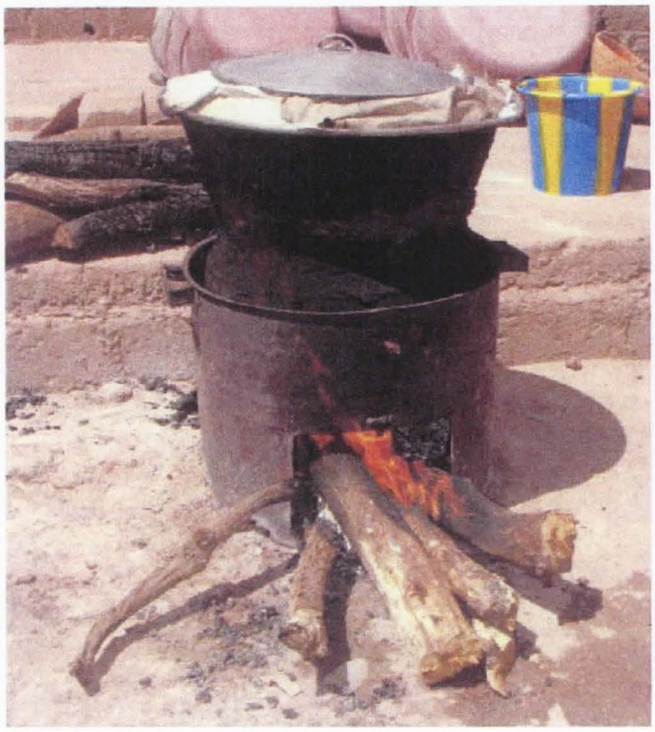
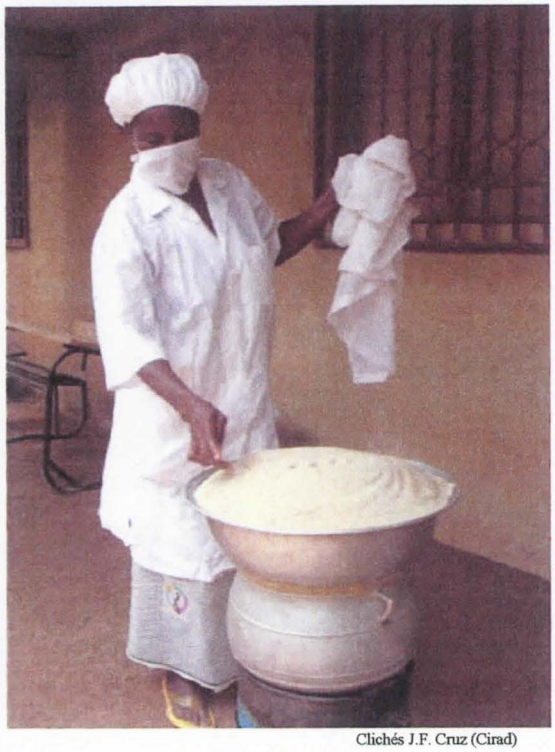


Fig.14. Fonio whitening and precooking diagram

[1] M. Rivier, J-F Cruz. 2007. Étude de la précuisson du fonio au sein de petites entreprises de transformation à Bamako (Mali) et à Ouagadougou (Burkina Faso). Projet FONIO. Cirad. Montpellier. 22p.





Clichés J.F. Cruz (Cirad)

Fig.15. Fonio precooking on wood stove

Fig.16. Fonio precooking on gas stove

The precooking equipments (or ustensils) used (stove, pot, metal pan) are very "rustic". Women need several units to precook large quantities of fonio (more than one hundred of kg) with several batches for each operation). Nevertheless these equipments are locally manufactured, and therefore, available and of accessible price. Between two batches, the operators are obliged to withdraw the pieces of wood ignited and after, to put them again. This operation presents unpleasant effects as well as fire hazards. On the wood stove, it is possible to appreciate the induced energy losses visually, simply by observing the flames which escape largely around the pot.

In Ouagadougou, some women prefer to use as much as possible the gas-burner in order to save energy. Measurements carried out confirm the observations well. The precooking of 1 kg of fonio needs 2.800 kJ with a wood stove and only 660 kJ on a gas-burner (4 times less!).

Solutions to lower energy consumption at SMEs level could be to use improved burner such as gas burner (e.g. Telimagaz commercialized by Total Company in Burkina Faso)

Cliché: Total -Burkina

Fig.17. Telimagaz (double gas stove)

Fonio parboiling

In 2008, experiments of fonio parboiling will be done in IER on 30 kg grain by using a steam parboiler « Cirad/PASAL » usually used on rice and that should be adapted to fonio.

2.1.3. Developing equipments adapted for drying fonio grain and products (task 1.3.)

The objective of task 3 in the workpackage 1 is to continue the mechanization of drying technologies in order to facilitate women labour.

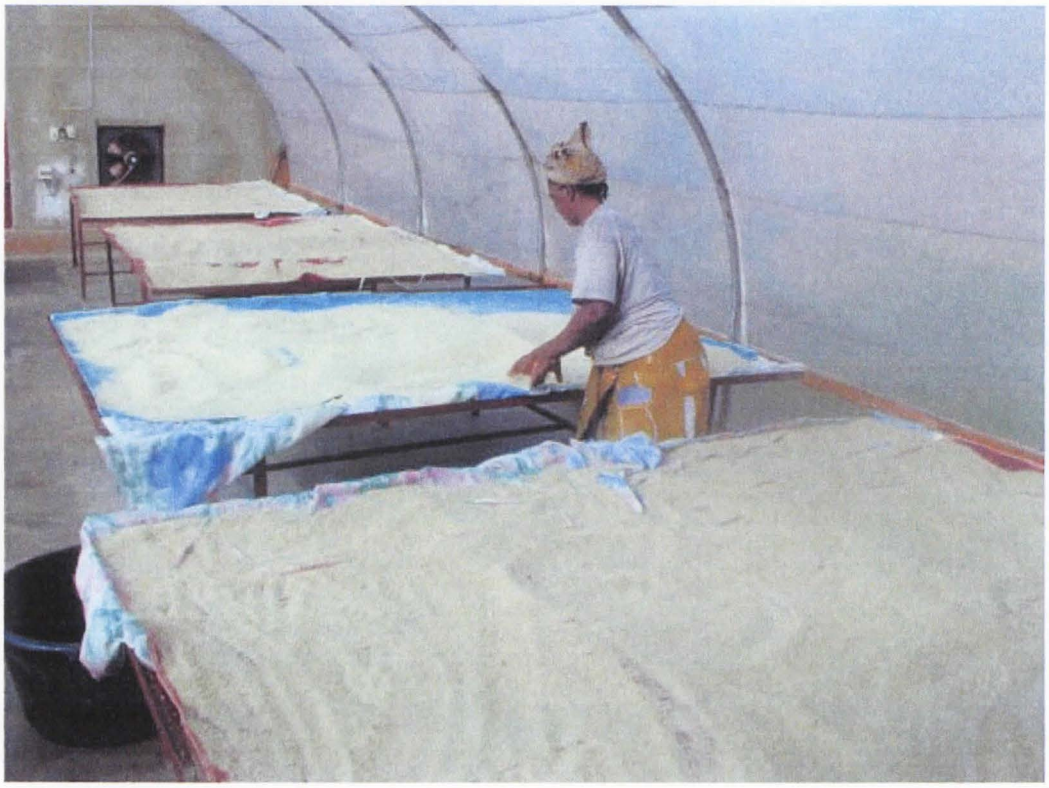
Last year, this activity was focused on drying. 2 types of driers have been manufactured in Mali and set up in small enterprises producing precooked fonio: a counter current cross-flow gas drier (CSec-T) set up in Danaya enterprise and a greenhouse ventilated solar drier (CSec-Serre) in Ucodal enterprise.

This year, experiments were conducted with them in the local enterprise conditions during two different seasons (dry and humid) and their performance were compared to that of other gas and solar driers (Fac 2000 and Hohenheim).

Main results

The greenhouse ventilated solar drier is equipped with 8 tables. The upper part of them is made of a wire screen on which precooked fonio is spread for drying. After one steam cooking, the product is pounded to break down the cooked blocks, and then sifted manually for individualizing the grains, before spreading it on mats put on each wire screen. In that enterprise, drying starts usually after the production of precooked fonio at around 3 to 4 p.m. during one day till 1 to 3 p.m. next day. Just after cooking, fonio humidity was around 34–36% (w.b.) and decreased down to 5-9% after drying.

Drying capacity varied from 320 to 400 kg per day, depending of the quantity of fonio spread on each table screen (40 to 50 kg).



Clichés J.F. Cruz (Cirad)

Fig.18. Fonio drying in the greenhouse solar dryer (CSec Serre)

The experiments carried out with this equipment were satisfactory during dry season and even during humid season in term of drying time, final moisture content and drying capacity.

The processor seemed very satisfied with this equipment; she would like to build a second one in parallel. The advantages of this drier underlined by her are:

- lower handlings : the product can stay inside the drier all night long, even when it is raining
- protection of the product against bad weather, birds, dust ...
- rapid drying (only one day) of any product at lower temperature 50-60°C
- same results whatever the season (dry, humid)
- lower cost in energy

However, she mentioned some points that should be easily improved:
- deformation of wire screens not enough resistant to high loadings of cooked product and screen mesh too large (lost of product)
- difference between the standard size of mats available on markets used to protect wire screens and the size of trays

She would like to replace wire screen by a metal plate for each table and ceiling ventilators that mix the air by blades.

The counter current cross-flow gas drier (CSec-T) is composed of three sections, each one containing 4 trays (12 trays in total). Hot air is introduced under the trays and distributed all through them. 8 kg of precooked fonio are spread on each tray, which means 96 kg per drying. Since 4 to 5 h are necessary to dry one batch of 96 kg, 2 or 3 batches (190 to 290 kg) can be treated per day. During the experiments conducted by IER, fonio humidity was around 27–35% (w.b.) just after cooking and decreased down to 5-6% (w.b.) after drying.

Clichés J.F. Cruz (Cirad)

Fig.19. The cross flow drier (CSec-T) at Danaya Company in Bamako

According to the processor, this drier has several advantages:
- there was no difference between a drying in humid or in dry season resulting in a good energy efficiency
- gas consumption was lower compared to other gas drier (Fac 2000).

The main inconvenient was the frequent handlings of trays (inversion of trays each 30 min) to get an efficient drying. The second inconvenient should be a less of homogeneity of air distribution between sections, the left section from where hot air is introduced being hotter than the right part.

The activity on washing which was supposed to start during this second year of the project could not be implemented in 2007 and should be considered during the third year.

2.1.4. Characterizing different fonio varieties at physical, technological level and identifying the varieties the most adapted to mechanical processing (task 1.4)

The objective of task 4 in the workpackage 1 is to identify fonio varieties the most adapted to mechanical processing and look at the effect of cropping system on their physical, biochemical and technological characteristics.

Fonio ecotypes were collected by WP6 and WP5 in Mali, Guinea, Burkina Faso and sent to WP1 Cirad Montpellier: 15 varieties from Cinzana IER experimental station in Mali sent by WP6 in December 2006 and a collection of local varieties bought directly at farmers' (3 varieties per village, in 4 villages per country),and sent by WP5 in may 2007, more precisely 13 from Mali, 11 from Guinea and 15 from Burkina Faso, in total 39 varieties.

These varieties have been characterized at physical and biochemical level. Their dehulling and milling properties have been compared and their cooking properties determined.
Presently, varieties from Cinzana station Mali and local varieties from Guinea and Burkina were analyzed. The analyses of the 13 local varieties from Mali are in progress.

2.1.4.1. Methodology used

Cleaning and dehulling fonio paddy grain

Before dehulling, fonio paddy grain was cleaned (per batch of 100 g of grain) through an Alpine air jet sifter by using a 1000 µm mesh sieve to remove large particles (other grains, stones, straw) and a 710 µm mesh sieve to remove fine particles (dust, immature grains). It was then dehulled with a Satake laboratory dehuller usually used for rice and adapted to fonio grain size: rubber rollers in contact, minimum of ventilation, batch of 100 g of paddy grain dehulled in two passages.

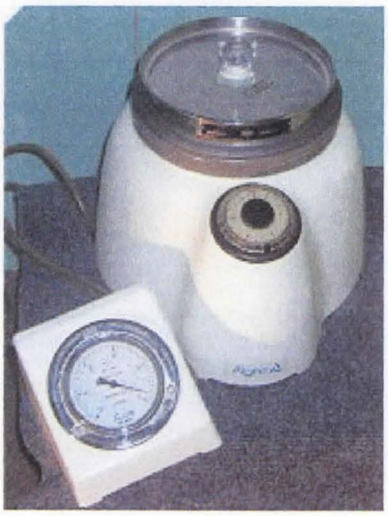
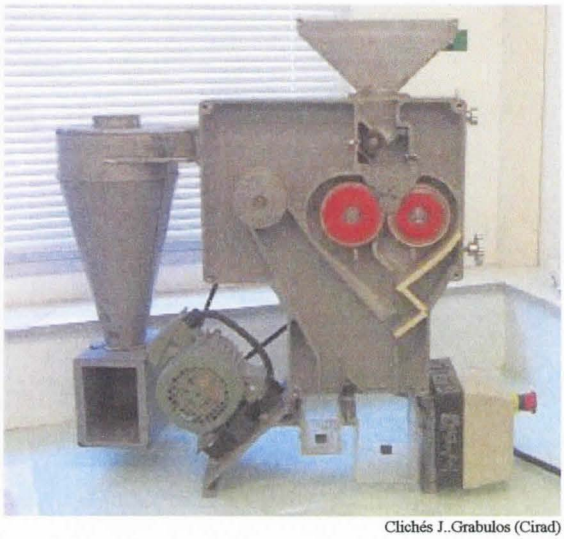


Fig.20. Alpine air jet sifter



Clichés J..Grabulos (Cirad)

Fig.21. Rubber rolls huller

Dehulling properties were determined by measuring the dehulling yield defined as the percentage of dehulled fonio grain weight report to paddy fonio grain weight.

Milling dehulled fonio grain

Dehulled fonio grain was milled with a Satake laboratory abrasive mill usually used for rice and adapted to fonio grain size after reducing the milling chamber size and surrounding it with a fine wire mesh. 80g of dehulled grain was milled during 1 min 15 with an abrasive plate turning at high speed around a horizontal axis.

Clichés J..Grabulos (Cirad)

Fig.22. Fonio whitening in laboratory

Milling properties were assessed through milling yield which is defined as the percentage of milled grain weight report to dehulled grain weight and through the percentage of brokens weight report to milled grain weight.

Washing and cooking milled fonio grain

Milled grain was separated from bran, dust and sand by washing it in distilled water in two steps according to the traditional way. It was then dried at room temperature during 48 h in an air conditioned room till its water content decreased to about 12 %.

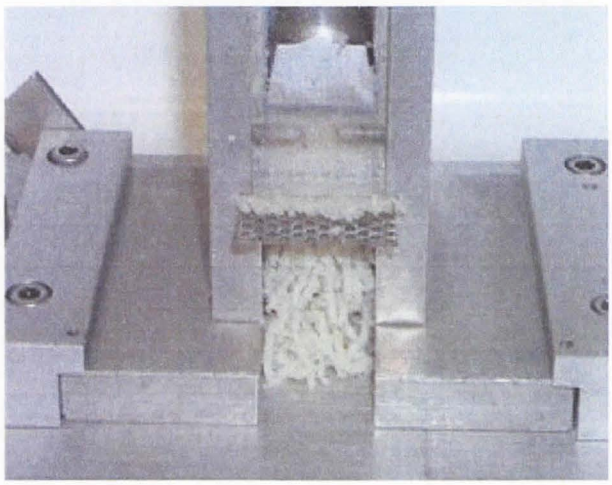
60 g of milled fonio grain was cooked three times during respectively 10, 12 and 10 min by using a Vitasaveur steam cooker containing 1 l of distilled water. Before each steam cooking, the grain was rehydrated with 30 ml of distilled water, in total 90 ml (one time and half weight compared to milled grain weight as traditionally). Cooking tests were performed in duplicate for each fonio variety.

Clichés J..Grabulos (Cirad)

Fig.23. Fonio washing and cooking in laboratory

Cooking properties of milled fonio grain was determined by measuring swelling properties of grain during cooking and consistency of cooked grain.
Swelling properties was defined as the quantity of water absorbed by grain during cooking in g / 100 g of dried cooked fonio. It was determined after dehydrating about 3-5 g of cooked grain in an oven at 100°C during 24 h.

Cooked grain consistency was measured with an Instron universal food testing machine by using extrusion tests. One hour after cooking, the grain maintained in an oven at 35°C during one hour, was transferred in an Ottawa cell (7.5 cm^2 extrusion area) equipped with a 2 mm mesh screen and preheated also in a water bath at 35°C. As the piston was compressing the sample (at a 100 mm/min constant speed), an increasing compressive force (in Newton) was recorded till a plateau (corresponding to the extrusion force) when the product was going through the screen. The firmer the consistency of cooked grain, the higher the extrusion force. The average extrusion force between two limits was chosen to assess cooked fonio consistency. Consistency tests were performed in duplicate for each sample of cooked fonio.



Cliché J..Grabulos (Cirad)

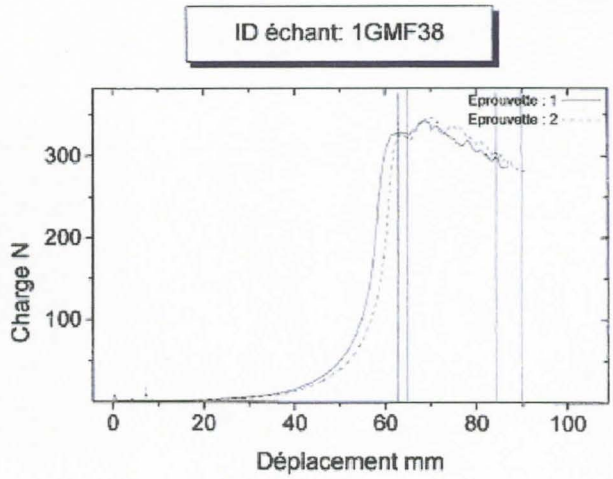


Fig.24. Mesure of fonio grain consistency in laboratory

Chemical analyses of milled fonio grain

Lipid content of milled fonio grain was performed according to the Soxhlet extraction method by using a Tecator Soxtec HT distiller. Lipids were extracted with diethyl ether at 100°C and measured (in % d.b.) after evaporation then desiccation of the extracts in an oven at 100°C during 15 min. Protein and mineral contents are in progress.

Multivariate analyse

All the data obtained for each technological or cooking trait of each variety were analyzed statistically. A Principal Component Analysis (PCA) was performed using Statistica 4.0 on all the ecotypes per country without any missing trait value.

2.1.4.2. Main results

A Principal Component Analysis was run on five quality traits analyzed for all the ecotypes from Mali, Guinea and Burkina Faso: milling yield, percentage of brokens, lipid content of milled grain, consistency and swelling power of cooked grain.

13 fonio ecotypes from Cinzana experimental station in Mali

The three first axes explained 95.4% of the variance, the first, second and third axes accounting for 48.5, 30.1 and 16.8% respectively. Variable loading showed that axis 1 was mainly explained by milling yield that accounted for 36.9% of global inertia of the axis opposed to percentage of brokens that accounted for 35.3%. This is in agreement with the negative correlation observed between milling yield and percentage of brokens. Axis 2 was strongly determined by grain consistency for positive values, and by swelling power for negative values. These traits explained 40.5 and 39.9% of the variability, respectively. This was also in agreement with the negative correlation observed between consistency of cooked grain and swelling power. Axis 3 was determined by lipid content of milled grain explaining 49.9% of inertia.

Scores of the 13 ecotypes based on the first plan of the PCA showed a variability of the five grain quality traits among the ecotypes which were well distributed in the plan. Varieties such as *Pon de Madougou* and *Sanogola* appeared more friable with a lower milling yield compared to *PéBê, TamaBê, Kassagara* or *Tioi*. *Pon de Boré* located in the bottom of the plan in the vicinity of swelling power loading showed good cooking properties with a low consistency value and a high swelling power value. It was opposite to *Tama* which presented firmer cooked grain, usually less appreciated by local population.

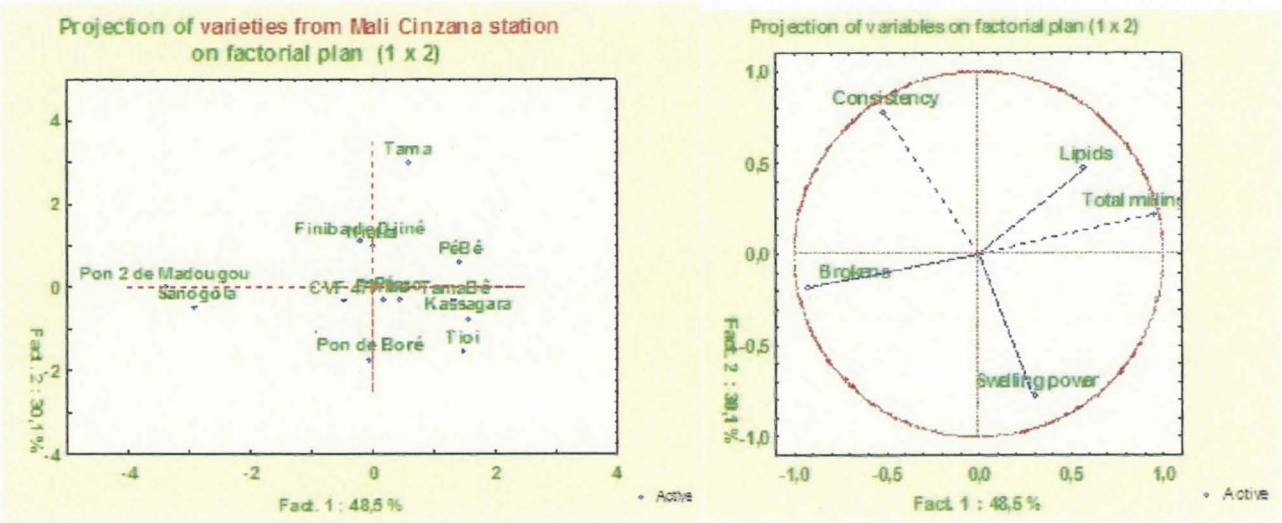


Fig.25. Principal Component Analysis for ecotypes from Mali

11 local fonio ecotypes from Guinea

The three first axes explained 92.3% of the variance, the first, second and third axes accounting for 54.2, 22.7 and 15.4% respectively. For these local varieties from Guinea, variable loading showed that axis 1 was mainly explained by milling yield and cooked grain consistency that accounted together for 59.6% of global inertia of the axis opposed to swelling power that accounted for 26.1%. In that case, it was found negative correlations between swelling power and consistency or milling yield. Axis 2 was strongly determined by percentage of brokens which explained 74.9% of the variability. Axis 3 was determined by lipid content of milled grain explaining 86.1% of inertia.

Scores of these 11 ecotypes based on the first plan of the PCA showed here too a variability of the five grain quality traits among the ecotypes which were well distributed in the plan. A group of varieties fitted with high values of swelling power trait such as *Souloukou manié*, *Fonibagbé*, *Siragué Dané* opposed to *Keleyaningbé*. *Kokounin* showed a high milling yield and *Yaouko* a high percentage of brokens in the standardized laboratory conditions of fonio milling.

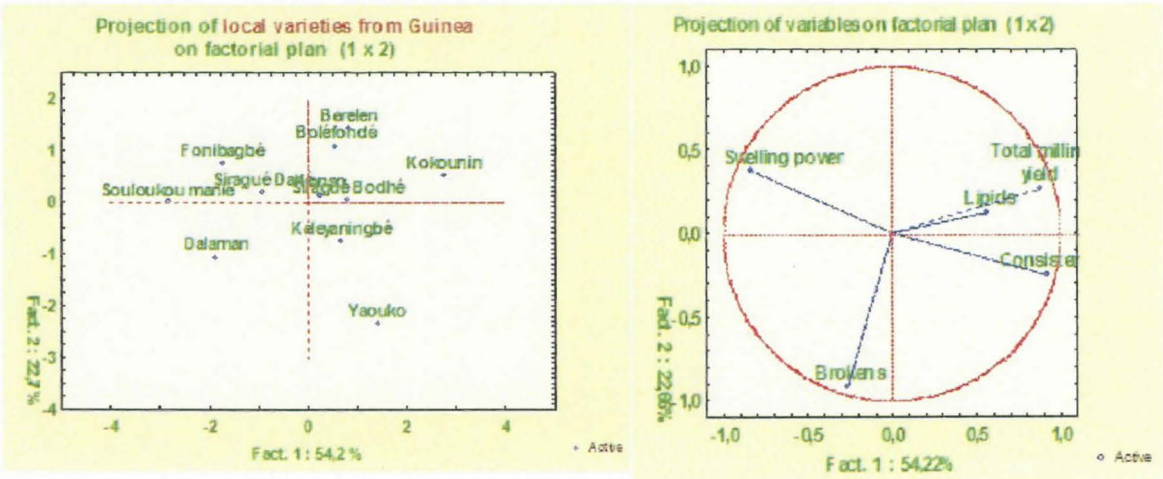


Fig.26. Principal Component Analysis for ecotypes from Guinea

15 local fonio ecotypes from Burkina Faso

The three first axes explained 97.7% of the variance, the first, second and third axes accounting for 53.9, 26.6 and 17.2% respectively. Variable loading showed that axis 1 was mainly explained by milling yield that accounted for 34.3% of global inertia of the axis opposed to percentage of brokens that accounted for 26.5%. This is in agreement with the negative correlations observed between milling yield and percentage of brokens. Axis 2 was strongly determined by grain consistency for negative values, and by swelling power for positive values. These traits explained 63.5 and 31.6% of the variability, respectively. This was also in agreement with the negative correlations observed between consistency of cooked grain and swelling power. Axis 3 was determined by lipid content of milled grain explaining 63.6% of inertia.
Scores of the 15 ecotypes based on the first plan of the PCA showed a variability of the five grain quality traits in the ecotypes which were well distributed in the plan. One variety stand apart from the others in the left/up quadrant, in the direction of percentage of brokens: *Fungban*, more easily broken during milling. A group of three varieties *Tenaïlé*, *Funigbé*, *Warr*, located in the bottom of the graph on both sides of the second axis and fitting with high values of consistency, should be firmer after cooking compared to another group such as *Foniba, Woussangué, Témaigbé*, in the upper part of the graph, which swelled better and appeared softer. Some varieties were concentrated on the right part of the graph in the direction of high values of milling yield and lipid content: *Wanwoulé, Pébio, Péfoso, Pémousso, Wonotono, Funigwé*, opposed to *Fungban, Vissan, Funlô*.

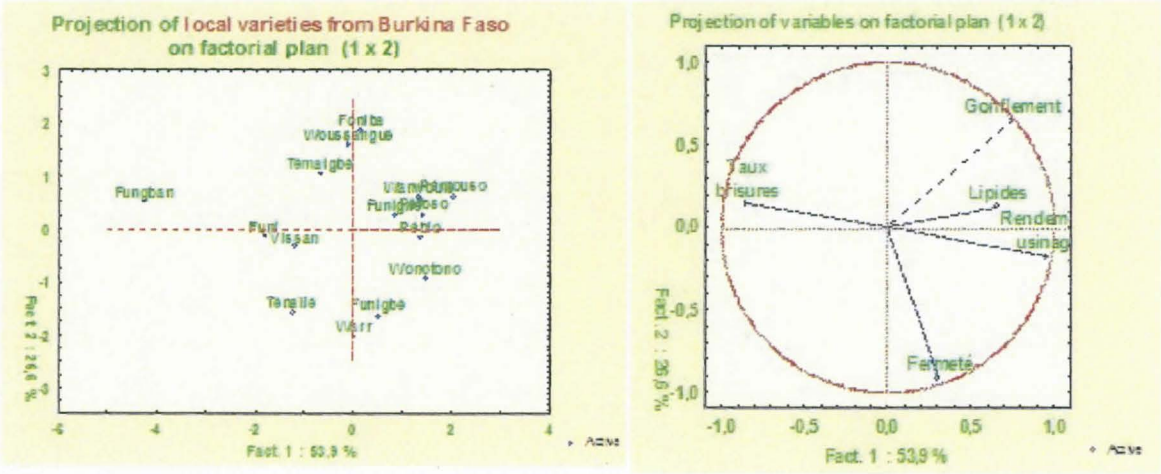


Fig.27. Principal Component Analysis for ecotypes from Burkina

During next year, all of these technological data will be compiled with agronomical data by WP6 to fill an individual specification sheet per cultivar. 12 ecotypes grown in the three countries of the project with two locations per country will be sent to Cirad by WP6 for technological analysis. The objective of this study will be to analyse the effect of cropping system on milling and cooking properties.

Deviations from the project workprogramme, and corrective actions taken

During the second year of the project, there were two deviations in the work programme

- in task 1.1 where the identification of quality criteria of milled and cooked fonio achieved in Mali the first year did not start in Guinea as previous, since local conditions would not be safety enough. In 2008, it will be seen how to start this activity in Guinea.

- in task 1.3. which was supposed to focus on the development of equipments for drying but also for washing. Unfortunately, the Cirad scientist in charge of this activity was operated on in the middle of the year and, due to following serious complications, he did not start work again, till now. This scientist is a specialist in this domain and actually it seems quite impossible to replace him for pursuing the researches.

List of deliverables, including due date and actual/foreseen submission date

De l N°.	Deliverable name	W P N°.	Date due	Actual/ Forecast delivery date	Estimated indicative person-months *)	Used indicative person-months *)	Lead contractor
1	Synthesis on quality criteria of cooked fonio and consumer preferences	1	12	28	2		Cirad
2	Laboratory protocols on assessment of cooking quality	1	24	26	3		Cirad
3	Paper on the relation between sensorial tests, instrumental tests and physico-chemical characteristics of fonio	1	24	33	2		Cirad
4	Paper on physical and mechanical properties of fonio grain as well as starch and rheological properties of cooked fonio	1	22	33	2		Cirad
5	Equipments for washing, cooking and drying developed and validated in local enterprises	1	30	33	6		Cirad
6	Manufacture drawings of equipments for drying, cooking, washing, available	1	33	32	2	1	Cirad
7	Report on acceptability tests of parboiled and precooked fonio products by local and European populations	1	24	33	2		Cirad
8	Booklet addressed to processors for producing high quality products for exports	1	30	30	2		Cirad
9	List of fonio ecotypes with good agronomic and technological qualities, adapted to mechanical processing	1	33	33	6		Cirad

List of milestones, including due date and actual/foreseen achievement date

Milestone no.	Milestone name	WP n°.	Date due	Actual/Forecast delivery date	Lead contractor
M1.1.	Start up workshop to define concerted approaches for WPs	1	1	Done in March 06	Cirad
M1.2.	Quality criteria and consumer preferences of cooked fonio identified.	1	12	15 (in Mali)	Cirad
M1.3.	Ventilated solar dryer built, month 12, and tested, month 21.	1	12, 21	Done in Dec 06 Done in Oct 07	Cirad
M1.4.	Physical and mechanical properties of fonio grain and starch and rheological properties of cooked fonio determined.	1	18	30	Cirad
M1.5.	Relevant process and equipment principles for precooking and parboiling identified.	1	24	28	Cirad
M1.6.	Acceptability tests of the new products with local and European people performed, month 30.	1	30	30	Cirad
M1.7.	Equipment of washing, cooking, parboiling manufactured, month 24, and tested, month 30	1	24,30	30,32	Cirad
M1.8.	Physical, biochemical, technological and organoleptic characteristics of widely used ecotypes determined.	1	30	30	Cirad
M1.9.	Quality norms of new products proposed.	1	30	30	Cirad

2.2. Work package 2 - Nutritional aspects of fonio and fonio products

Responsible scientist: Dr. Inge D. Brouwer - Wageningen University (The Netherlands)
Other participating contractors: IER (Mali), Cirad (France), Cirdes (Burkina)
Other collaborator: Université d'Abomey Calavi (Benin)

Participant n°	2	4	1	5	Other
Organisation name	WUR	IER	Cirad	CIRDES	UAC
Country	The Netherlands	Mali	France	Burkina	Benin
Staff	**Ms. I. Brouwer**	Ms. Y. Koreissi	Ms. G. Fliedel	E. Vall A Kanwé	R. Dossa Ms. N. Fanou

Staff of the Wageningen University (division of Human Nutrition) is leading the Working Package 2: Nutritional aspects of fonio and fonio products, and has therefore the overall scientific and technical responsibility for the supervision of (1) the implementation of the proposed studies, (2) the data collection, analyses and interpretation, and (3) the reporting of the results, for those parts of the studies which concern the nutritional quality of fonio and fonio-products and the nutritional role fonio plays and may play in an healthy daily diet for especially West-African people.

Workpackage objectives

The general objective of WP2 is to determine the nutritive value of fonio and fonio products and its contribution to nutrient intake and nutritional status.

Main objective 1:
To analyse the nutritional value of different fonio varieties, milled fonio and diverse fonio products (pre-cooked, parboiled).
Work objectives of reporting period:
1a - To determine variation of nutrient value of fonio varieties
1b - To determine effect of processing on mineral content of fonio and fonio products
1c - To validate and update the Mali food composition table

Main objective 2:
To determine the role of fonio in the dietary pattern.
Work objectives of reporting period:
2a - To determine food and nutrient intake of women of reproductive age in Bamako
2b - To identify factors predicting intention to consume fonio among women of reproductive age in Bamako

Main objective 3:
To determine the contribution of fonio to nutrient intake and nutritional status.
Work objective of reporting period:
3a - To determine nutritional status and iron status of women of reproductive age in Bamako

Progress towards objectives – tasks worked on and achievements

2.2.1. Analysis of the nutritional value of different fonio varieties, milled fonio and diverse fonio products (pre-cooked, parboiled) (task 2.1.)

Fonio (*digitaria exilis*) is a staple food which is increasingly consumed in many communities in West Africa, especially in urban areas (Konkobo-Yameogo et al., 2004). In Mali, many studies have been done regarding its nutritional value. However, there is little information about iron, zinc, and their inhibitors contents such as phytate and polyphenol even in the Mali food composition table. Fliedel et *al*, in 2003 has shown a slightly significant level of iron and zinc in Fingoloni fonio variety in Mali. It was demonstrated that iron level in mechanically dehulled grain is 38.8 ppm of dry matter for iron and 33.4 ppm of dry matter for zinc. For milled fonio the levels of iron and zinc are 27.3 ppm and 21.8 ppm of dry matter, respectively. This level of iron is slightly less than that of other cereals such

as millet, and sorghum and close to that of milled rice with however a higher content of zinc even after washing the grain and removing all the sand. The Mali food composition table does report on nutrient composition of fonio. However, the nutrient composition refers to one specific variety of fonio, the nutrient composition of other varieties is unknown. In the food composition table, data are available for the whole grain of fonio, but no information is available about fonio products such as milled fonio, precooked and cooked fonio. Data on zinc content of fonio is also not available for the majority of the foods. Value of phytate is completely missing. Based on the above, this activity was sub-divided into three sub-activities: (i) determination of variety of nutrient value of fonio varieties, (ii) determination of effect of processing on mineral content of fonio and fonio products, and (iii) Validation and updating of the Mali food composition table.

2.2.1.1. Study on determination of variation of nutrient value of fonio varieties

Methods: Twelve (12) varieties samples of fonio were purchased from 34 farmers, 3 farmers per variety in 2 regions of Mali Republic where in total together approximately 70% of the national fonio production was produced from 1989 to 2000. From each farmer 10kg of fonio sample was purchased. Thousand (1000) grams of each fonio variety were processed in the laboratory using a standardized cleaning procedure. Samples were sent to Wageningen and in the laboratory of the Division of Human Nutrition, laboratory samples of paddy grain and mid-wet fonio were prepared for biochemical analysis of macronutrient, Fe, Zn and phytate level. The laboratory samples for phytate analyses were sent to the ETH (*Eldgenossische Technische Hochschule* or Swiss Federal Institute of Technology) in Zurich, Switzerland. All other analyses are carried out within Wageningen University.

Results: Analysis is still in progress and first results are expected in January 2008. Preliminary results were presented in the form of a poster during the 7th International Food Data Conference in Sao Paulo, 22-24 October 2007.
Y. Koreissi, I. Brouwer, P. Hulshof, M. Zimmermann. *2007. Nutritional aspects of fonio and fonio products. Poster in 7th International food data conference. Food Composition and Biodiversity. Sao Paulo, Brazil, October 21-24, 2007.*

2.2.1.2. Study on determination of effect of processing on mineral content of fonio products

Methods: Two (2) varieties of fonio were used (1 commonly used pure variety *Péazo* and 1 mixed variety as bought on the market). For each variety, a part was parboiled following the procedures developed by WP1. Thousand (1000) grams of each variety, both normal and parboiled version, were processed in the laboratory of IER using a standardized processing procedure developed in collaboration with WP1. Samples were sent to Wageningen and in the laboratory of the Division of Human Nutrition, laboratory samples of mid-wet fonio and pre-cooked fonio were prepared for biochemical analysis of macronutrient, Fe, Zn and phytate level. The laboratory samples for phytate analyses were sent to the ETH in Zurich, Switzerland. All other analyses are carried out within Wageningen University. .

Results: Analysis is still in progress and first results are expected in January 2008. Preliminary results were presented in the form of a poster during the 7th International Food Data Conference in Sao Paulo, 22-24 October 2007 (see above).

2.2.1.3. Validation and update of the Mali food composition table

Desk review of Mali food composition table

A qualitative good food composition database is needed to estimate actual dietary intake of energy, iron and zinc, and to determine the contribution of fonio to these. The aim of the first step in validating and updating the Mali food composition table (TACAM, 2004) was to assess the quality of the TACAM through a desk review. A selection of 25 frequently consumed foods (based on the results of the 24-hour recall and food-weighed record) and 11 nutrients was made for quality evaluation.
In the process of generating food composition data, 7 essential stages can be identified: Description of food, sampling plan, number of samples, sample handling, analytical method, ability of the laboratory split in accuracy and precision, the mode of expression of the final results.

Methods: Step 1: The origin of the nutrient data was identified for protein, fats, available carbohydrates, fibre, calcium, iron, zinc, vitamin A and vitamin C. If documentation was available, quality evaluation was done by a modified expert systems approach as developed by Holden *et al* (2002).
Step 2: Based on the multi-nutrient expert system approach, decision trees were designed consisting of evaluation questions covering all 7 stages mentioned above. Answers to the questions were based on available documentation. Each answer was scored and the sum of all scores yielded a confidence code (cc), A, B or C. Code A indicated that users could have considerable confidence in the nutrient value, B indicated that users could have confidence although some problems existed regarding the data on which the value was based and C indicated that the value was of low quality.
Step 3: Both nutrient values from the TACAM (2004) without available documentation and values assigned cc C in step 2 due to a lack of sufficient documentation, were evaluated by the comparison method. Each nutrient value was compared with values from other food composition sources. When the TACAM-value was included in the range used for comparison, the value was accepted. In case the TACAM value was not included in the range, Dixon's outlier was used to see if the TACAM value significantly deviated from the values reported in other food composition sources. For significant outliers a recommendation was made for replacement and for missing values in TACAM (2004) a recommendation was made for update.

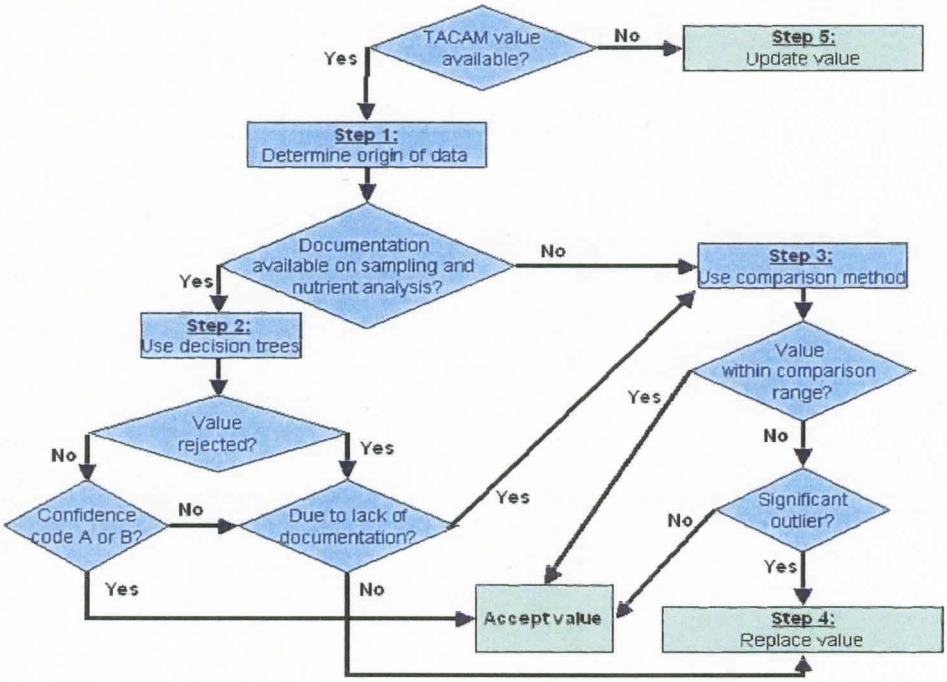


Fig.28. Overview of method

Results: In total 100 values were evaluated in step 1, no cc A was reported. 184 values were evaluated in step 3 of which 167 were accepted. For 46 values ≤1 source for comparison (17.7%) was found.

Description	n	% of total values evaluated (n=248)
Values accepted after step 2, cc=B	48	19.4%
Values accepted after step 2 and 3	46	18.5%
Values accepted after step 3	121	48.8%
Values nominated for replacement	18	7.3%
Values nominated for update	15	6.0%

Table4. Updating Mali food composition table (TACAM)

Discussion and conclusion: When using the decision trees adequate documentation on sample handling and quality control was often lacking. Ranges used for comparison were based on small numbers of values. The proposed food composition table can be used to assess dietary intake of energy, iron, zinc, and their absorption inhibitors and enhancers. However, the appropriateness of the replaced and updated values is not certain and additional nutrient analyses are recommended.

Final validation and update of Mali food composition table
Based on the desk review, all foods consumed during the food consumption study (n=90) and the 13 nutrient values of interest (representing 1170 values) were evaluated and, if necessary updated, using the procedures developed in the desk review. This resulted in the final so-called FONIO food composition table 2007 (see Appendix2)

2.2.2. Determination of the role of fonio in the dietary pattern (task 2.2)

This activity was sub-divided into two sub-activities: (i) a study to determine food and nutrient intake of women of reproductive age in Bamako, and (ii) a study to identify factors predicting intention to consume fonio among women of reproductive age in Bamako.

2.2.2.1. Study to determine food and nutrient intake of women of reproductive age in Bamako

This study was carried out to (i) determine the mean nutrient intake of the women; (ii) assess the adequacy of iron, zinc, and vitamins A and C intakes in relation to the dietary reference intakes, (iii) investigate the relationships between the probability of adequacy and the socio-demographic factors and (iv) determine iron bioavailability of the diets of the women.

Methods: A total of 108 apparently healthy non-pregnant, non-lactating women in the age of 15 to 49 years were randomly selected from the households, using a three-stage cluster sampling. Background information on marital status, number of children, education, occupation, and current health status is collected prior to the 24-h recall by means of a questionnaire.

The daily food intake of the subjects was assessed by a 24-hour recall method on two non consecutive days. Data were collected by well-trained local assistants through semi-structured interviews based on questionnaires mentioning specific probes to help the respondents remember all foods consumed throughout the day. The total amount of the cooked food and the amount consumed by the respondent were measured in household units. Conversion factors from household unit to weight were determined afterwards. Weights were measured using digital dietary scales Soehnle, Plateau Art Nr 65086 (22lb), maximum range 10 kg, accuracy 2 g (0.1oz). A food frequency questionnaire was used to determine the frequency of consumption of different fonio-dishes. An individual dietary diversity questionnaire was administered to determine the different food groups consumed the day before the interview.

Cliché: WUR

Fig.29. Survey in Bamako

Results: Analysis of the results from the 24-hour recall and the individual dietary diversity are in process. Nutrient intake will be computed by the VBS 3.0 programmes using the updated FONIO food composition table (see above). Table shows the socio-economic characteristics of the population.

Characteristics	Category	Percent
Age	15-18	15.4
	19-30	38.5
	31-49	46.2
Number of children	No	33
	1-3	33
	4-11	34
Education	Illiterate	34.6
	Primary school	29.8
	Secondary and higher school	23.1
	Literate or Islam school	12.5
Income generating activities	None	47.1
	Retailer	26.0
	Employee	6.7
	Other activities	20.2

Table5. Socio-economic characteristics of the population

Preliminary analysis of the nutrient intake is shown in Table 3. The results indicate that about 95% of the women have an Fe intake below the recommended nutrient intake, whereas 86% has a zinc intake below the recommended intake.

Characteristics	Mean (n)	SD	95% CI
Age [years]	32 (101)	10.5	
Daily Fe intake [mg/day]	28.5 (35)	16.4	[22.8 ; 34.1]
% below Fe EAR (5%)	94.4%		
Daily Zn intake [mg/day]	6.9 (35)	2.6	[6 ; 7.8]
% below Zn EAR (5%)	86.1%		
Daily Ca intake [mg/day]	359.6 (35)	296.2	[257.9 ; 461.4]
Daily P intake [mg/day]	657.7 (35)	273.4	[563.8 ; 751.6]

EAR: Estimated average requirement

Table6. Micronutrient intake of women in reproductive age, Bamako

Preliminary analysis of frequency of fonio consumption is shown in next table . These results indicate that fonio is consumed by all women, but that the frequency of consumption is rather low. Most frequently consumed dishes are Djouka fonio (by 50.9% of the women) and Foyo (by 47% of the women). Most women do consumed these dishes 1-3 times a month.

Fonio based dish	1-3 times/mth	4-5 times/mth	> 5 times/mth
Djouka fonio (snack)	35.3	7.8	7.8
Fôyô	43.1	3.9	0
Fini zamé	2.1	0	0

Table7. Frequency of fonio consumption

Table below shows that the portion size consumed of fonio is relatively small (67.3 g SD 9.9) compared to rice (253.2 g SD 239.1) and millet (209.7 g SD 186.4).

Cereals	Average (n)	SD	Min	Max
Rice	253.2 (34)	239.1	37	1147
Millet	209.7 (15)	186.4	49	658
Fonio	67.3 (4)	9.9	56	79

Table8. Portion size of fonio (in grams) consumed compared to other staple foods

Preliminary conclusions: Women in reproductive age show a low Fe and Zn intake. Most women do consume fonio but not frequently. If consumed, the portion size is rather small compared with other staple foods such as millet and rice.

2.2.2.2. Study to identify factors predicting intention to consume fonio among women of reproductive age in Bamako.

Preparatory work
To develop the questionnaire for identification of factors predicting intention to consume fonio, an attribute-pile sort study was carried out among 26 women of reproductive age in Bamako. The main selection criteria were to be a volunteer and to have basic knowledge on fonio and fonio products as foods. All the selected women ate fonio and were involved in the study after giving their verbal informed consent.

Pictures of the two mostly eaten foods within each food group of the Mali food composition table were taken from market and in the households. The food attributes and pile sort was done in three steps: the pile setting, the food difference and the food attributes. For the pile setting, all the food pictures were showed to the women who were asked to set on pile all the pictures that belong together according to any criteria making sense to them, and to describe their criteria. The food difference method was used for fonio and other cereals. The women were asked to compare fonio with other main cereals (rice, millet) in order to identify the main differences and similarities of fonio compared to the other staple cereals. Finally, the food attributes method was applied only for fonio and fonio products. The women were asked to describe three main attributes: the outcomes (advantages and disadvantages) expected when consuming fonio products, the people and information sources which might influence, and the factors that would enhance or limit their fonio consumption.

Study on identification of factors predicting intention to consume fonio among women of reproductive age in Bamako
Iron and zinc deficiencies are of major public health concern in Mali (West Africa), particularly among women in reproductive age (15-49 years). Based on a high iron and zinc content, an increase in fonio consumption could contribute to a reduction in the prevalence of iron- and zinc deficiency. Understanding consumption behaviour would help in developing a comprehensive nutritional program towards the promotion of fonio consumption. This study aimed to identify factors that predict the intention to consume fonio among women in reproductive age living in Bamako, the capital city of Mali.

Methods: For this cross-sectional study, 108 women in reproductive age living in Bamako were selected by a three-stage cluster sampling. Data were collected by four well-trained local female interviewers, using a questionnaire. The items of the questionnaire (developed based on the preparatory work and literature research) were categorized according to the constructs of a combined model of the Theory of Planned Behaviour (TPB) and the Health Belief Model (HBM) (Figure below). Reliability analysis was performed to verify internal consistency within the constructs. Spearman correlations examined bivariate relations between constructs. Multiple regression analysis was performed in four models:
Model 1: IDEN = f (KNOWL, SUSC, SEVE, and VALU)
Model 2: INTEN = f (BARRI, IDEN, and ATB)
Model 3: INTEN = f (SUBJ, CONT, and CUES)
Model 4: BEH = f (BARRI, INTEN, and BARRI*INTEN)

The figure below shows combination of Health Belief Model and Theory of Planned Behaviour (based on: Sun *et al.*, 2006)

Key words:
KNOWL=Knowledge, SUSC=Perceived susceptibility, SEVE=Perceived severity, VALU=Health value, IDEN=Health behaviour identity, ATB=Attitudes towards behaviour, BARRI=Perceived barriers, SUBJ=Subjective norms, CONT=Control beliefs, CUES=Cues to action, INTEN=Intention, BEH=Behaviour, *b*=belief, *eb*=evaluation of belief, *mc*=motivation to comply.

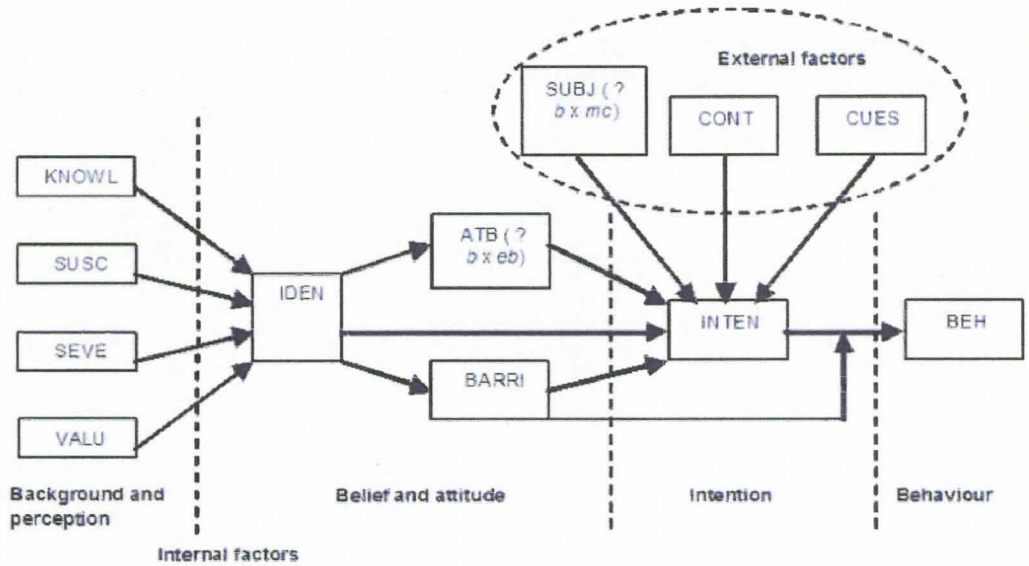


Fig.30. Combination of Health Belief Model and Theory of Planned Behaviour

Results
Results are given in table below. Reliability analysis demonstrated high reliability of the constructs (Cronbach's α between .77 and .95). Health value (stand. β=0.230, P=0.010) contributed significantly to the prediction of health behaviour identity. Health behaviour identity on its turn was significantly correlated with attitudes towards behaviour (r_s=.673, P=0.000) and perceived barriers (r_s=.332, P=0.000). Attitudes towards behaviour (stand. β=0.315, P=0.014) and subjective norms (stand. β=0.277, P=0.035) contributed significantly to the prediction of intention to consume fonio. Perceived barriers appeared to be a significant interaction term in the relation between intention and behaviour (stand. β=-0.717, P=0.043). The association between intention and behaviour was lower for the high-barrier group (score BARRI > 70, n=54) (r_s=.686, P=0.000), than for the low-barrier group (score BARRI ≤ 70, n=54) (r_s=.850, P=0.000). Intention was significantly correlated with fonio consumption (r_s=.780, P=0.000).

Model 1 (Y = Health behaviour identity)	*Standardized β*	*P*	Model 2 (Y = Intention)	*Standardized β*	*P*
Knowledge	0.218	0.075	Health behaviour identity	0.025	0.840
Perceived susceptibility	0.082	0.439	Perceived barriers	-0.109	0.283
Perceived severity	0.225	0.058	Attitudes towards behaviour	0.315	0.014
Health value	0.230	0.010			
Model 3 (Y = Intention)	***Standardized β***	***P***	**Model 4 (Y = Behaviour)**	***Standardized β***	***P***
Subjective norms	0.277	0.035	Perceived barriers	0.302	0.098
Control beliefs	0.152	0.114	Intention	1.398	0.000
Cues to action	-0.026	0.841	Perceived barriers * Intention	-0.717	0.043

Table9. Multiple regression analyses (n=108).

Discussion: Fonio consumption (behaviour) was self-reported, and being aware of the study purpose could have created social desirability bias in the answers. Also, respondents tended to agree with the statements of the questionnaire. Furthermore, a specific (higher educated) group was selected by chance, due to the sampling procedure.

Conclusion: To promote fonio consumption, intention to consume fonio could be increased by focusing on positive subjective norms and attitudes towards fonio consumption. General health consequences of fonio consumption should be emphasized in order to stimulate a positive attitude. Finally, a reduction of the barriers to consume fonio will encourage that intention leads to actual fonio consumption.

2.2.3. Determination of the contribution of fonio to nutrient intake and nutritional status (task 2.3)

This activity comprised a study on the nutritional status and iron status of women of reproductive age in Bamako.

Methods: One hundred and eight healthy non-pregnant, non-lactating women aged 15 to 49 years were randomly selected from the households based on their written informed consent, using a three-stage cluster sampling (UNICEF, 1996). Of the 108 selected, 63 did not participate in the anthropometry and blood samples collection, given a non response rate of 38%. Background information on marital status, number of children, education and occupation were collected prior to the measurements.

Anthropometry consisted of weight and height measurements. Body weight was measured early in the morning, from fasting subjects, using a SECA platform spring balance precise to 0.1kg. The scale were placed on a horizontal surface and calibrated before each measurement session using a standard weight. Subjects were weighed wearing a minimum of clothing Gibson, 2005). Height was measured using a microtoise (body measuring tape MZ10017). Measurements were performed with the subject standing without shoes on a horizontal surface against a will with heels together, chin tucked in and body stretched upwards to full extent and head in the Franckfurt plane; heels, buttocks and shoulders in contact with the wall to which the microtoise is attached. Measurement was read at nearest 0.1 cm.

Blood samples were collected early in the morning (7.00 am) from fasting subjects by medical and health specialists. From the women in sitting position, 8 ml of venous blood was withdrawn in two different tubes:

- 6ml tubes for serum biomarkers such as transferrin receptors, serum ferritin, C-reactive protein; and serum zinc
- K2 EDTA 2ml tubes containing anticlotting for Haemoglobin and MCV.

The 6ml tubes were homogenised 5 times at 180°C, taking care of haemolysis in the tubes, and were allowed to clot at room temperature for 30min. They were then centrifuged for 10 min at 3000g, and allowed clotting again for 30 min at 25°C (room temperature). Finally the samples were split in Nalgen tubes 1.2ml, with pipette Pasteur 3ml as follows: 1ml for serum zinc; 0,5ml for c-reactive protein; 0,5ml for ferritin; and 0,5ml for transferrin receptor. The tubes were frozen at -30°C, protected from sunlight before sent to The Netherlands for analysis.

The K2 EDTA 2ml samples were homogenised 8 to 10 times, à 180°C taking care of haemolysis in the tubes. Haematological biomarkers were analysed immediately after blood withdrawal.

Serum transferrin receptor was measured by enzyme-linked immunosorbant assay. Serum ferritin and CRP concentrations were measured by radioimmunoassay. Serum zinc concentration was measured using the flame atomic absorption spectrophotometry. Haemoglobin concentrations and mean corpuscular volume were analysed immediately by a Horiba ABX Micros 60-OT16 device. The device was checked for quality control before and after the total measurements of the day and calibrated after each 10 samples analysis.

Preliminary results:

The study population had an average BMI of 23.7 (SD 5.6), a hemoglobine level of 12.3 g/L (SD 1.4), a serum ferritin level of 39.9 µg/l (SD 48.5), and a CRP-level of 5.3 (SD 15.0), see table below.

Characteristics	Mean (n)	SD	Minimum	Maximum	95% CI	SE
Age [years]	32 (101)	10.5	15	49		
BMI [kg/m2]	23.7 (64)	5.6	16.6	41.1	[22.3 ; 25.1]	0.7
Hemoglobin [g/dl]	12.3 (67)	1.4	6.5	15.3	[12 ; 12.7]	0.2
Ferritin [µg/l]	39.9 (67)	48.5	1.7	268.7	[28 ; 51.7]	5.9
C-Reactive Protein [mg/l]	5.3 (67)	15.0	< 1	98	[1.6 ; 9]	1.8

Table10. Nutrition and iron status of women of reproductive age in Bamako

Table 8 below shows that 29.2% of the women were overweight or obese, while 16.9% of the women could be considered as moderate to mildly underweight.

All groups	Percent	groups [cut-offs]	Percent
CED	16.9	Moderate CED [16-16.9]	4.6
		Mild CED [17.18.4]	12.3
Normal	53.8	Normal [18.5-24.9]	53.8
Overweight and obesity	29.2	Overweight [25-29.9]	16.9
		Obese class1 [30-34.9]	6.2
		Obese class2 [35-39.9]	6.2

Table11. nutritional status of the women (n=65)

Looking at the age-distribution, the level of underweight reduces with age, while the level of overweight and obesity increases with age.

Nutritional status	Age classes [years]		
	15-18	19-30	31-49
CED (%)	7.8	6.3	3.1
Normal (%)	6.3	20.3	26.6
Overweight and obesity (%)	1.6	10.9	17.2

Table12. Crosstabulation nutritional status and age (n=64)

Concerning the iron status of women, 37.3% of the women show anemia of which 1.5% has severe anemia. About 21% show iron deficiency (Table 14)

Iron status	Percent	Iron status_all groups [cut-off]	Percent
Anemia	37.3	Severe anemia [<7.0 g/dl]	1.5
		Moderate anemia [7-9.9 g/dl]	3.0
		Mild anemia [10-11 g/dl]	32.8
Normal	62.7	Normal [>12 g/dl]	62.7

Table 13: prevalence of anemia (n=67)

Serum ferritin classes [cut-offs]	Percent
Low [<10 µg/l]	20.9
Normal [10-300 µg/l]	79.1

Table 14: Iron status using serum ferritin (n=67)

Crosstabulation of anemia and serum ferritin levels (Table 15) indicate that 20.9% of the women have iron deficiency anemia, and 16.4% has iron deficiency without anemia. The CRP levels (Table 16) show that 14.9% of the women have elevated CRP levels indicating the existence of infections.

Hb Classes	**SF Classes**	
	Low	**Normal**
Severe anemia (%)	1.5	0
Moderate anemia (%)	3.0	0
Mild anemia (%)	16.4	16.4
Normal (%)	0	62.7

Table15. Crosstabulation serum ferritin and Hb (n=67)

CRP	**Percent**
Normal [≤7.5 mg/l]	85.1
High [>7.5mg/l]	14.9

Table16. Chronic inflammation level by CRP (n=67)

Preliminary conclusions: Women in reproductive age in Bamako do show both underweight and overweight. Iron deficiency is prevalent, and is probably mainly due to a low iron intake.

Deviations from the project workprogramme, and corrective actions

The preliminary analysis of activity 2.1; 2.2 and 2.3 indicate that there is a high prevalence of iron deficiency among women of reproductive age in Bamako, probably due to a low iron intake. The frequency and portion size of fonio consumption is low, but there are possibilities to increase fonio consumption by focusing on positive attitudes of fonio consumption and reducing the perceived barriers. However, the question whether an increase of fonio consumption could contribute to a reduction of iron deficiency cannot yet be answered, as the following questions still need to be answered: (i) is the level of iron in fonio and fonio products high enough, (ii) is the level of phytate in fonio and fonio products low enough, or (iii) does parboiling increase the iron level of fonio and fonio products? If the answers on these questions are all 'no', it has probably no sense to continue with bioavailability studies.

However, as indicated by results of WP5, in rural fonio production areas, most people do rely on fonio as their main staple food. Based on the preliminary results, we may expect that the iron status of women and children in these areas is low. Improving iron intake of fonio-based diets may be reached by adding cereals with a high native-phytase content. If the answers on above questions are 'no', WP2 proposes to continue with iron-bioavailability studies of fonio-based diets, especially fonio-porridges with added cereals with relatively high native phytase levels. It is expected this decision will be taken in February-March 2007.

List of deliverables, including due date and actual/foreseen submission date

Del N°.	Deliverable name	WP N°.	Date due	Actual/ Forecast delivery date	Estimated indicative person-months *)	Used indicative person-months *)	Lead contractor
10	Report on nutritive values of fonio varieties, milled fonio and fonio products	2	27	32	2		WUR
11	Paper on importance of fonio in the dietary pattern and the relationship with socio-economic status	2	21	25	2		WUR
12	Paper on the relationship between fonio consumption, nutrition adequacy and nutrition status	2	24	30	2		WUR
13	Report on methodology for the measurement and reproducibility of Fe bioavailability using stable isotope technique	2	30	30	1		WUR
14	Paper on the Fe bioavailability of from usual fonio-based diets	2	36	36	1		WUR
15	Paper on the effect of (new) processing techniques of fonio on Fe bioavailability	2	36	36	1		WUR
16	Paper on effect of ascorbic acid on Fe bioavailability of low versus high phytate content fonio products	2	36	36	1		WUR

Justification of putting off deliverable deliverance:

Deliverable 10 and 12 are delayed due to a delay in chemical analysis of the fonio samples and blood samples. Deliverable 11 is delayed due to the relative long time it took to update the food composition table. Based on the decision to be taken (see above), the content of deliverables 13-15 may change, and deliverable 16 may be dropped.

List of milestones, including due date and actual/foreseen achievement date

Milestone no.	Milestone name	WP n°.	Date due	Actual/Forecast delivery date	Lead contractor
M2.1.	Start up workshop to define concerted approaches for WPs	7	1	Done in March 06	Cirad
M2.2.	Updated food composition table especially concerning fonio varieties, milled fonio and fonio products,.	2	12, 27	Done partly in Dec06 Scheduled 27	WUR
M2.3.	Important role of fonio in dietary pattern and reasonable contribution of fonio to nutrient intake established.	2	24	Scheduled 25-30	WUR
M2.4.	Methodology for measuring Fe bioavailability using stable isotope technique established	2	18	Scheduled 30	WUR
M2.5.	Lowering effect of processing techniques of fonio on phytate content and increasing effect on Fe bioavailability established	2	36	36	WUR
M2.6.	Effectiveness of improving Fe bioavailability of processing techniques compared to that of ascorbic acid established.	2	36	36	WUR

2.3. Work package 3 - The demand for new products and its effects on income generation and distribution

Responsible scientist: Dr. Sandrine Dury – Cirad (France)
Other participating contractors: ENDA Graf (Senegal), IER (Mali) and IRAG (Guinea)

Participant n°	1	4	5	7
Organisation name	Cirad	IER	IRAG	ENDA Graf
Country	France	Mali	Guinea	Senegal
Staff	**Ms. S. Dury** N. Bricas	L. Diakité M. Traoré	Ms. M. Ndiaye	B. Touré O. Gueye

Workpackage objectives and starting point of work at beginning of reporting period

The general objective of WP3 is to assess the drivers and the characteristics of the demand for innovative products from African and export markets and to understand the effect on income generation and distribution of the development of these products in comparison with the old ones.

The specific objectives are the following
- On African markets, to understand how innovative fonio products are accepted by the consumers. Identify the key factors (variables) and measure their specific effect on the demand and on the decision of purchase.
- On European markets, to identify and rank the consumers' expectations regarding fonio products. Evaluate the willingness to pay for fonio products.
- To assess the generation and the distribution of incomes by different existing innovative products, and to estimate the possible impact of the development of new products on income distribution among the different stakeholders of the market chain.

The specific objectives for the reporting period were
- to analyse the data collected in 2006 in Mali concerning the demand for new products (Task 3.1). The results had to be presented and discussed with the main processors, before continuation.
- to study of the demand in Europe: protocol, survey and analysis(Task 3.2).
- to define and to launch activities concerning WP3 and WP4 in Guinea which is quite specific compared to Mali, regarding new products and enterprises and to analyse first results of activity 3.3. concerning Mali (2006 survey)
- to decide on which activity to focus for 2007 and 2008.

Progress towards objectives – tasks worked on and achievements made

2.3.1. Evaluation of the demand of new fonio products in African markets (task 3. 1)

2.3.1.1. Data analysis

Surveys done by Cirad WP3 and WP1 (Ms. S. Blancher) and IER (Ms. F. Bore Guindo) between June and October 2006, about the demand for new products and new characteristics were analysed during the first term of 2007. A final report is not available but data and analysis were used to write a paper for an international seminar [2] and to submit a paper for an international review.

The analysis show that consumers in Bamako actually pay for "traditional" quality characteristics such as colour or level of processing. For very rough products such as pre-milled or milled not washed, they also pay for an immaterial attribute: the declared origin (they pay more for fonio coming (or declared coming) from Guinea, than fonio coming from Mali). Concerning new fonio product, it seams that the

[2] S. Dury, V. Meuriot, G.Fliedel, S. Blancher, F. Boré Guindo, D. Dramé, N. Bricas, L. Diakité, J-F Cruz.
The retail market prices of fonio reveal the demand for quality characteristics in Bamako, Mali. *106th seminar of the European Association of Agricultural Econsomists :* "Pro-poor development in low income countries: Food, agriculture, trade, and environment". 25-27 October 2007 – Montpellier, France.

variation in retail prices do not reveal the demand for quality characteristics since it depend essentially on the trademark and the place of sale (supermarket, grocery).

In addition to the previous analysis presented in the first activity report, concerning the relation between the market retail prices and the different characteristics of the products, socio-economic profiles of consumers and final uses of the different types of fonio are assessed (see tables below).

		Decorticated fonio	Milled (not washed) fonio	Milled (washed) fonio	Precooked fonio
Number of observation (100% in column)		58	99	17	65
Buyer Job	Employee	**21,1%**	10,3%	5,9%	20,0%
	Independent worker	**49,1%**	24,7%	**35,3%**	9,2%
	Student	7,0%	10,3%	**0**	6,2%
	Civil servant	1,8%	9,3%	**29,4%**	**47,7%**
	Unemployed	1,8%	3,1%	0	0
	Retired	0	4,1%	23,5%	7,7%
	Housewife	19,3%	**38,1%**	5,9%	9,2%
Buyer education level	Primary school	**77,2%**	**77,3%**	35,3%	20,0%
	Secondary school	10,5%	10,3%	**52,9%**	**35,4%**
	More than secondary school	12,3%	12,4%	11,8%	**44,6%**
Buyer origin	Region of production of fonio	**51,8%**	**58,8%**	35,3%	45,3%
	Region with no production	48,2%	41,2%	**64,7%**	**54,7%**
Status of the buyer	Mother	62,1%	74,7%	35,3%	60,0%
	Employee	6,9%	7,1%	0	6,2%
	Father	5,2%	3,0%	**47,1%**	20,0%
	Other member of the family	25,9%	15,2%	17,6%	13,8%
Age of the buyer	Less than 20	17,5%	16,5%	5,9%	3,1%
	Between 21 and 35	**73,7%**	**75,3%**	35,3%	23,1%
	Between 36 and 50	8,8%	8,2%	**58,8%**	**47,7%**
	More than 51	0,0%	0,0%		**26,2%**
Sex of the buyer	Man	12,5%	8,3%	**64,7%**	**29,2%**
	Woman	87,5%	91,7%	35,3%	70,8%

Table17. Buyer's profile according to the type of purchased fonio

		Decorticated fonio	Milled (not washed) fonio	Milled (washed) fonio	Precooked fonio
Number of observation (100% in column)		58	99	17	65
Recipe	Djouka	**48,3%**	30,3%	11,8%	10,8%
	Foyo	48,3%	69,7%	82,4%	81,5%
	Other	3,4%	0,0%	5,9%	7,7%
Occasion	For sale or gift	**44,8%**	21,2%	**0,0%**	**12,3% (gift)**
	Week-end meal	6,9%	18,2%	23,5%	**38,5%**
	Familial or religious event	13,8%	13,1%	29,4%	13,8%
	Regular meal	32,8%	45,5%	35,3%	35,4%
	Other	1,7%	2,0%	11,8%	0,0%
destination	Family consumption	53,4%	40,4%	**94,1%**	**84,6%**
	Processing for sale (restaurant)	**24,1%**	**26,3%**	5,9%	1,5%
	Processing for gift	**8,6%**	**11,1%**	0,0%	0,0%
	For a gift (with no process)	**12,1%**	**22,2%**	0,0%	12,3%
	Other	1,7%	0,0%	0,0%	1,5%

Table18. Destination of the product according to the type of purchased fonio

Buyers' profiles and final uses are quite different according to the types of purchased fonio. This confirms the hypothesis that the retail market is segmented between "old products" and new ones. Initially we thought that *milled-and-washed* fonio (fonio "*blanchi lavé*") was part of what we called "traditional" products, but the present results show their consumers and uses are closer to those of the precooked fonio.

The main characteristics of the two segments are as follows:

- The buyers of the « traditionnal segment » are mainly female (90%). They mainly buy fonio in the markets. They usually buy decorticated or milled fonio. The buyers usually do by themselves or with the help of an assistant (maid or family member or employee) the last operations of processing: pounding if necessary, cleaning, washing, and the cooking. 25% of the purchases are used in an income generating activity: sale of *djouka* in schools or in the street, or sale of meal including fonio in small restaurants. 25% of the purchases are given, and half are consumed at home.
- The buyers of the « new segment » have a higher level of education, many of them are male (between 30 and 60%), and many are civil servants (from 30 to 50%). The regularly go shopping in the supermarkets and they often possess a vehicle. They usually buy washed or precooked fonio. Most of the fonio is consumed at home and a small part is given.

The first segment concerns the great majority of buyers in Bamako. At this stage of the study, we are not able to say if the buyers of precooked or washed fonio have reduced their consumption of the other types of fonio (decorticated or milled not washed), or if they have increased their overall consumption of fonio.

2.3.1.2. Feed back to processors

During the WP3&WP4 workshop in Bamako (May/June 2007) a meeting was organised at IER Sotuba Centre to report to the processors the main results concerning the market chain (IER, Ecofil) the price of the different attributes (Cirad), and the typology of the processors (Enda).

Cliché: J.F. Cruz (Cirad)

Fig.31. Meeting with processors in Bamako

2.3.1.3. In Guinea: The image of fonio is changing. Roasted fonio is a new product.

A WP3 staff member (N. Bricas, Cirad) went to Guinea (17-29 April 2007) to a join mission with partners from Guinea (Irag), from Senegal (Enda) and with the project Leader (Cirad). It was conclude that the image of fonio was changing in Guinea. For more and more people, fonio is no longer considered as a cereal for the poor but, on the contrary, as a luxurious good. Innovation in Guinea concerns mainly the mechanization of the milling with the dissemination of the GMBF dehuller. However, the group found out a product that had not been described yet in former investigations: the "roasted fonio". This fonio is milled, then washed and roasted in large pans. Its colour changes since it loses its transparency (see photo below). This product is not sold in Guinea, but it is a part of a common recipe. Tests of acceptability by the European consumers were done on that specific product during the second term 2007. Unfortunately, the samples contained sand and the consumers rejected them.

Clichés: J.F. Cruz (Cirad)

Fig.32. Roasted fonio (left) and precooked fonio (right)

2.3.2. Evaluation of the demand for fonio products and specific characteristics in European markets (task 3.2)

2.3.2.1. Methodology

Study was implemented by Cirad with the assistance of a student (Ms. M. Lebrun), at Montpellier SupAgro, for a period of six months (June- December 2007) to assess the acceptability of fonio products by non African natives in Europe. Two series of research were conducted: an in-depth qualitative phase and a quantitative phase.

The first phase concerned interviews of 27 women and 11 men in Montpellier (Hérault, France). These persons were selected among acquaintances that were used to buy or consume quinoa, a dry grain cultivated in South America and sold in Europe, often under fair trade or organic labels. People consuming quinoa were supposed to be open to new exotic product and possibly future consumers of fonio. Most of the selected persons usually cook at home, or at least were able to cook. They were first ask to react to the name "fonio" and then to the product. Then they had to choose a sample between 4 different types of fonio: whole grain, roasted, white pre-cooked, and white precooked with black grains. They cooked the sample by themselves at home using one of the proposed recipes, and they were contacted again to give their feedback.

The second phase was based on a short questionnaire administrated to 355 persons in Montpellier in five different locations where it was possible to encounter potential buyers: one organic store, two fair trade stores and two open peasant markets. The questionnaire was designed into three main parts: the first one consisted in collecting the spontaneous reactions about the different three existing packages. The open question "*what may encouraged or discouraged you to buy this product?*" was asked and answers where encoded afterwards. The packages were presented one after the other. Then, a conjoint

analysis was done based on five attributes: organic, faire trade, produced by small producers, produced in Africa, and whole/white grain. And the third part concerned knowledge of fonio, comparison of the different packages, and personal characteristics of the buyer.

Most statistical analyses were done using Excel or SPSS 15.0 for windows. For the conjoint analysis, 12 different cards (see figure below) were evaluated by the interviewees. They had to give an appreciation from "1: *I am not interesting at all in buying this product*" to "4 : *I am very keen on buying it*".

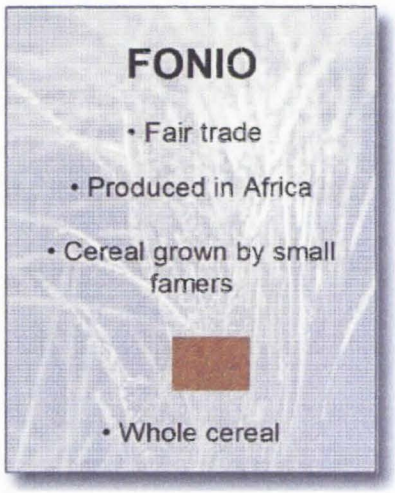


Fig.33. Example of cards n°6 (14*11cm)

An "ordered logit regression" was used to estimate the contribution of each attribute to the note given (1, 2, 3 or 4). The intercooled stata 9 software was used.

2.3.2.2. Main results

Acceptability of the grain, the name and the recipes

"fonio" does not seem to be very attractive to French consumers : the grain is *a priori* considered as an undetermined or even a non edible thing : 34 associations were done with edible things (semolina, sugar, salt...), and 19 associations were done with non edible things (sand, insect eggs...). In addition the name "fonio" sound strange, queer and not especially attractive to most interviewees. The cereal is neither considered as tasty nor original. 8 persons said they liked the taste, 4 said they hated it, and the other 13 said the taste was neutral (positively for 7 and negatively for 6).

The results of the cooking were mitigated. Altogether (see table below) half of the tests were considered as a success. This is not a very good result since someone who never tried a product will not be encouraged to try it a second time if she/he failed to cook it at the first time. More attention has to be given to help non connoisseurs to get through it.

	Couscous	**Chocolate cake**	**Frying pan with Vegetables**	**Tabbouleh with fruits**	**Tabbouleh**	**Stuffed tomatoes**	**Other recipe**	**Total**
Frequency of choice	7	9	20	6	15	4		**61**
done	3	7	12	2	9	2	7	**42**
succeed	3	5	4	1	3	2	2	**20**
loved	3	2	4	1	3	2	2	**17**

Table19. Results of the test of the different recipes

Note that several persons made a kind of polenta (soft porridge) with fonio and liked it. This is different from the African traditional recipes and tastes.

Ms. M. Lebrun suggests proposing either classical recipes that were a success, but with experienced cooks, (chocolate cake, couscous, or stuffed tomatoes) or very simple and quick recipes (like polenta) that still have to be elaborated.

Reactions to the existing packages

Clichés: J.F. Cruz (Cirad)

Fig.34. Usual fonio packages in France (*Racines, Ethiquable* and *Gaia*)

The *Gaïa* package was preferred by half of the sample (47%), while *Ethiquable* was chosen by 31% of the interviewees, and *Racines* by 13% of the interviewees. 9% of the sample was enable to chose one of the three proposed packages. 200/355 persons quoted the organic label of the Gaïa package. It was positive for these persons. It was the most quoted positive characteristics of all the three packages.

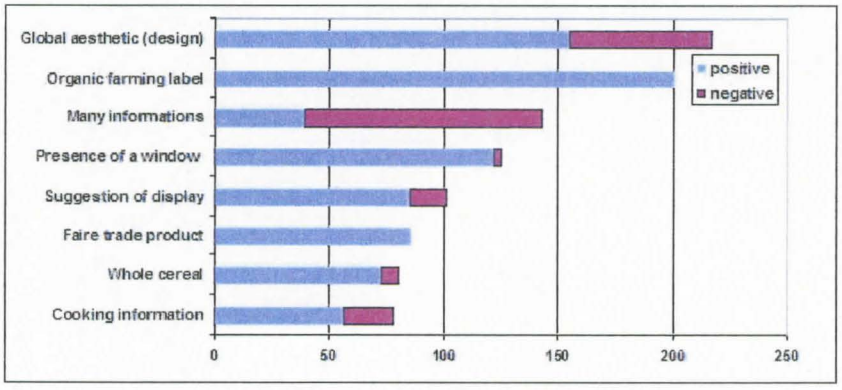


Fig.35. Spontaneous evaluation of the *Gaia* package (355 persons)

Concerning the *Ethiquable* package, there is no official label, but it is clearly stated "fair trade" with a logo with two persons and a globe (see figure below). The presence of a window was considered positively. And above all, the global aesthetic of the package was quoted by most people (either positively or negatively) for the three packages. For the Gaia package many persons (104/355) complained about the excess of information. However, this was the preferred package for most people.

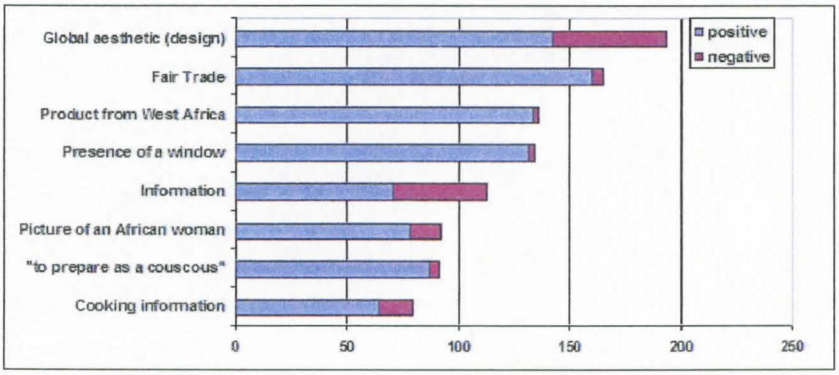


Fig.36. Spontaneous evaluation of the *Ethiquable* package (355 persons)

The analysis showed no effect of the gender, size of the household, level of life, consumption habit, on the choice of a package : it is always Gaia first, then *Ethiquable*, then *Racines*. On the opposite, the age, professional activity, special food diet, acquaintance of fonio, place of survey had an impact on the choice. Younger persons (less than 25 years old) and students preferred the *Ethiquable* package, while persons with a special food diet (vegetarian or gluten free diet) disregarded the *Ethiquable* package (presumably since it is the only one with no food composition table).

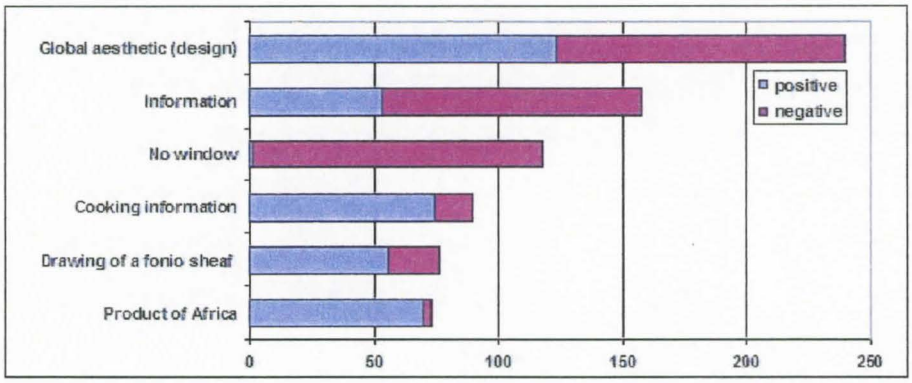


Fig.37. Spontaneous evaluation of the *Racines* package (355 persons)

Preference for the different attributes

Altogether the consumers gave a higher note (preference) to organic label, fair trade label, small producers, whole grain and Africa, in a decreasing order.

The tested combinations of attributes showed that addition is positive but the utility of two attributes is usually less than the addition of each separated utility. At the same time, it is higher than each individual attribute. As a consequence, a product with, for example, both organic and faire trade labels is preferred than a product with only one. Two exceptions: (i) organic and small producers are independent (bp is not significant). (ii) the addition of "Africa" and "small producers" is negative: the global utility is less than the utility given by only one of these attributes.

Effect of socio-demographic characteristics, context and food habit on preferences

The figure below summarizes the results of the effects of sociodemographic and food habit characteristics on the preference (note given) for fonio. One should note that there was no effect of the size of the household nor the level of life on the note given. Some results are difficult to interpret, but some are consistent: for instance, it is not surprising that people with a special diet tended to prefer fonio than others. Persons who know fonio or who have already heard about it gave a better note.

"Give a higher note" or "Prefer the product" than

Women	Men
Less than 50 years old	More than 50 years old
Retired	All other professional activities
Regular consumer of fair trade	Non or occasional consumer of fair trade
Non or occasional consumer of organic products	Regular consumer of organic products
Vegetarian or gluten free diet	No special diet
Connoisseur of fonio	Non connoisseur of fonio
Interview in an organic store	Interview in market or fair trade store

Fig.38. Effect of socio-economic variables, context, food consumption habit on the consumers' preferences

Concerning the preference for the different attributes the study showed that:
* *Fair trade* is equally appreciated by all categories of persons (gender, age, special diet) belonging to all categories of household (level of life, number of members…)
* *Produced in Africa* is not very differently segmented except for non consumers of organic product who tend to dislike this attribute compared to other consumers. Indeed, Africa is far, and consuming products from so far is seen as non ecological (high transportation and pollution costs).
* *Produced by small farmers* is more preferred by youngest and oldest persons, household with no children, non consumer of organic products.
* *Organic* is more appreciated by household with children compared to household without children, and by persons who do not consume fair trade products.
* *Whole cereal* is more preferred by households with children, persons with special diets, consumer of organic products, persons interviewed in organic stores

Conclusion

The results showed that many people are interested both by the design of the packages, the information (recipes) and the different labels (organic, fair trade). Concerning the labels, organic is dominant, followed by faire trade. Both of them are well known and advertised. They are official and easily recognisable by a specific logo. For other attributes based on the information concerning the production place (Africa) or social conditions (small producers), the analysis showed a weaker preference. This may be due to the fact that these attributes are not guarantied by any certifiers, nor known, nor attractive in themselves. To a certain extent, the addition of these two latter attributes (Africa and small producers) had a negative impact on the note given by the consumers. Whole grain is preferred to white grain by the "average" consumer, but differences existed in-between consumers. Even if the market is not clearly segmented yet, one can distinguished a group of persons more interested in organic and health, who were more attracted by "organic" label and "whole products". Usually they had children and they took care of their own health and the health of their children. They were not interested in the African nor small producer aspects. Another segment, but closely interlinked with the first one, concerned younger persons, or with no children, more attracted by faire trade and related attributes (Africa or Small farmers). However, advertising both on small farmers and on the African origin of the product may have a negative impact.

2.3.3. Impact on income generation and distribution of the development of new products (task 3.3)

Mali

A national assessment of the ***filière*** (market chain) was discussed between the different partners involved in WP3 and WP4 in Mali and with the project leader, especially during a two weeks mission in Bamako (29 May-2 June 2007). In 2001-2002 the production reached about 21 000 metric tons, while home consumption was estimated to reach about 9 000 metric tons. A large part of this difference can be explained by the several losses due to the different stages of process between production and consumption. Using technical coefficients established during the CFC project, altogether the national production of milled-and-washed fonio is estimated to about 13 000 metric tons. The difference with the quantity consumed at home is thus estimated to 4 000 metric tons. This quantity is possibly consumed out of home, in school (under the form of *djouka*) and in street restaurants (*djouka* or *foyo*). This is realistic since many of the interviewees are used to consume fonio out of home.

No reliable data are available about import (decorticated from Guinea mainly) and about export (pre-cooked mainly to USA and Europe). The different interviews we had with the main producers of precooked fonio allow estimating a volume range of production (around 300 metric tons) and of export (around 200 metric tons).

These same interviews gave us an idea about the employment generated by the mechanisation in the 11 small scale enterprises of processing and service (milling) we visited during our mission in June. About fifty permanent jobs and thirty temporary jobs have been created since 1990. 70% of these employments concern women. These figures have to be completed with the data collected by the WP4 team (O. Gueye) in different processing units.

Deviations from the project work programme, and corrective actions taken/suggested: identify the nature and the reason for the problem, identify contractors involved

Identification of the restaurants and gargotes selling Fonio in Bamako (Mali), Kindia (Guinea) or Dakar (Senegal) is not completed because of the complexity of the task: many small places, almost all informal activities.... It is difficult to say today if the national partners will be able to assess the number of restaurants selling fonio in each of these cities, but the probability of failure is great. It is sad since many people say that these small restaurants have a key role in the market chain. Then, it will be difficult to estimate the quantities sold in these restaurants and hence the number of jobs concerned by this activity.

List of deliverables, including due date and actual/foreseen submission date

Del N°.	Deliverable name	WP N°.	Date due	Actual/ Forecast delivery date	Estimated indicative person-months *)	Used indicative person-months *)	Lead contractor
17	Report and synthesis for processors on the willingness to pay for different innovations	3	15	25	3		Cirad
18	Paper about the role of individual and contextual variables in the demand for new fonio products in Africa and in Europe	3	21	23	9		Cirad
19	Report on the existing prices, costs, market margins and levels of employment	3	30	30	3		Cirad
20	Report on the impact of new products on income generation	3	30	30	5		Cirad

Justification of putting off deliverable deliverance:

D17 was initially due in March 2007 (month 15). End of 2006, it was decided to postpone to November 2007 (month 21). Finally, this deliverable will be delivered in January 2008 (month 25) after the analysis of European consumer survey is completed (December 2007).

D18 was presented to an international seminar end of October 2007 (month 22) and submitted after a few revisions in November 2007 (month 23) to the European Review of Agricultural Economics.

List of milestones, including due date and actual/foreseen achievement date

Milestone no.	Milestone name	WP n°.	Date due	Actual/Forecast delivery date	Lead contractor
M3.1.	Processors are identified in each country and involved in the project. They contribute and discuss with food technologist and market specialists what innovation may be possible for local markets	3	12		Cirad
M3.2.	Intermediate workshops (month 6, 18 and 26).	1 to 4 3&4 1 to 4	6, 18, 27	Done in June 06 Done in April 07 Done in October 07	Cirad
M3.3.	Processors are identified in each country and involved in the project. They contribute and discuss with food technologist and market specialists what innovation may be possible for exports.	3	20	20	Cirad
M3.4.	Information (price, cost, labour) from WP4 and WP5 is available.	3	15	15	Cirad
M3.5.	Final seminar	1-7	35	35	Cirad

2.4. Work package 4 - Small scale enterprises and innovation in product and process

Responsible scientist: Babacar Touré – ENDA Graf (Senegal)
Other participating contractors: IER (Mali), IRAG (Guinea) and Cirad (France)

Participant n°	1	4	5	7
Organisation name	Cirad	IER	IRAG	ENDA Graf
Country	France	Mali	Guinea	Senegal
Staff	Ms S. Dury N. Bricas J.F. Cruz M. Rivier	D. Dramé M. Traoré Ms B.F. Guindo	Ms M. Ndiaye	**B. Touré** O. Gueye Ms F. Ndoye P. Seck

Workpackage objectives

Enda Graf Sahel is involved in the FONIO project as leader of WP4. The overall aim of WP4 is to assess and explain the impact of developing new products and processes on the organization, strategies and economic results of micro- and small-scale enterprises (MSEs).

During the reporting period, the specific objectives are the following:
In Guinea:

- ✓ Identification, characterization and typology of fonio processing MSEs
- ✓ Survey on fonio product supplies and re-distribution networks (traditional, modern)
- ✓ Understanding the carriers of changes (players, process, impact, etc.)

In Mali:

- ✓ Completing the identification list of fonio MSEs in Mali to realize surveys in those enterprises (background, organization, operation, etc.).
- ✓ Characterizing and realizing the typology of Fonio MSEs
- ✓ Studying fonio product supply and distribution channels.
- ✓ Studying the relations between the various players
- ✓ Understanding how innovations (products, processes, techniques) have produced changes (description and analysis)
- ✓ Studying the various functions of MSEs and analyzing the logics, opportunities, constraints, strategies (innovations, product improvement, processes, etc.)

Progress towards objectives – tasks worked on and achievements

2.4.1. Typology and characterization of fonio processing enterprises in West Africa

The identity classification of fonio processing MSEs in West Africa is still a very complex task. That complexity is linked to the very nature of the enterprises based on their emergence, conception, role, organizational method, operation or expected results based on diversified types and forms. The notion of micro enterprises mainly used here and there is hybridized, or even composite. The content varies according to communities. First of all, in their organization, then in their relations to profits, and finally at the level of institutional approaches that are more attached to standardized norms. More often than not, those norms break off with the realities that they are attached. The referent does not comply with the same realities and the same forms of social construction. Besides, MSEs in Africa are set up and develop without being called companies. They are part of grassroots' economic and social initiatives, of which the functions and logics are built, re-adapted, adjusted according to the circumstances and empiric experiences.

They are far from being considered as companies, while they are companies indeed in the real sense of the terms of capital investment on production means, both material and human, on products manufacturing, distribution and marketing on the market, profit, job creation (self-employment or external employments), etc. But the type of capital investment, marketing process and the type of profit

have multiple, various and complex significances, considered in various contexts and that can have diverse meanings depending on the nature of the production structure.

Most of the enterprises studied are part of a category that is hardly comparable to those found in Europe or in the Americas. They are not opposite models, but rather have much specificity. West Africa offers various profiles of micro and small fonio processing enterprises. In the context of the program, these enterprises constitute the set of units that process and/or propose packaged or unpackaged fonio-based finished or semi-finished products.

In the three countries considered (Guinea, Mali, Senegal)it is possible to distinguish three main types of fonio enterprises: fonio processing enterprises, service providing enterprises, fonio distribution enterprises. There are about a hundred of them differently distributed across the named countries.

2.4.1.1. Fonio processing companies

These are enterprises mobilized for the processing and marketing of fonio-based finished or semi-finished products in plastic bags of 500g, 1kg, 5kg or bags of 20kg. There are over 70 fonio processing enterprises in the three countries, representing about 72% of all the processing, services and distribution units.

These units were created over the last two decades, from 1999 to 2006, and contribute to satisfy a crucial need for building new "futures" following the recurrent crises that have proceeded, went along with, and followed the periods of structural adjustment and the devaluation of the FCFA in 1994. The dwindling living standards and the various adjustments operated had weakened the middle-class and pushed vulnerable classes, particularly women, into daily precariousness. Many players, mainly women, then turned their hope towards the increase in value of local products, which, according to certain logics, should meet the requirements for competitiveness on the local and global market. Mali became famous in the fonio sector. Over fifty units, representing 77% of fonio processing enterprises emerged in that period.

In Senegal, a dozen of units were recorded, representing 16% of fonio processing enterprises that emerged during the last decade (1997 – 2005). The main activity of about half of these enterprises relates to services, i.e. primary and secondary processing. These types of enterprises are mixed enterprises. Most of them belong to farmers' organizations of which the main activity is husking and whitening fonio. But, at the same time, women affiliated to these networks organize themselves individually or collectively (networks of people engages in processing) to sell precooked fonio to other processing and distribution MSEs.

Although Guinea is the world leading fonio producing country (about 130 000 tons yearly), it still lags behind in terms of fonio processing and marketing. Only 6 finished and semi-finished products processing units were registered across the country.

In the three countries, fonio processing units are broken down into two major groups: micro-enterprises and small enterprises. These can be distinguished from each other by four main criteria: 1) the level of mechanization (husking machines, driers); 2) the installation of units outside dwelling places; 3)the level of production and marketing; 4) the form of ownership, which informs on the mode of ownership. The units are owned by individuals, families or communities (association).

NB: Mechanization (new processes) is considered such as the set of mechanic and technological innovations used to process fonio. Thus, various equipments manufactured and experimented in the context of previous projects (CFC Fonio, etc.) are acknowledged and validated as being the main innovations, which entail major changes in the structural organization, operation and economic operation of MSEs. These are particularly:

- ✓ Rotating sifter (cleaner)
- ✓ Fonio husking machines (i.e. GMBF fonio dehuller)
- ✓ Gas driers, « cross-flow » dryer (type CSec-T dryer,..)
- ✓ Solar dryer, greenhouse dryer (type CSec-Serre)

Fonio processing micro-enterprises

Fonio processing micro-enterprises are characterized by no or scarce use of modern equipment (husking machines, driers, etc.); fonio production is lower than 10 tons/year and home activities are still maintained. Micro-enterprises represent the overwhelming majority of fonio processing units: 72% in Mali, all of the Senegalese and Guinean units. They are more often community-owned (e.g. 5/6 in Senegal and 82% in Guinea). They belong to women's groupings, producer networks, associations; coops or family members, etc. Two groups are distinguished according to the use or not of mechanic equipment.

Traditional micro-enterprises
These are enterprises in which all processing operations are done manually. They can relate to the production of semi-finished products such as washed-out and whitened fonio or finished products such as precooked fonio. The quantities of products can vary a lot depending on the workforce mobilized and the level of production cycle. This is the case for most women buying husked fonio and whitening it, washing it and then selling it on daily or weekly local markets. The same applies to fonio people processing precooked fonio, who do not have the means to husk or whiten the fonio with a machine. There are four of them in Mali, and constitute the bulk of Guinean enterprises.

Semi-traditional micro-enterprises
Although these are enterprises that do not have husking machines on their own, they still can resort to those machines for husking and/or whitening the fonio. In this case, they refer to service providers or small enterprises that have husking machines, in return for 50 FCFA per kilo for both operations and 25 FCFAF for just whitening. 90% of micro-enterprises claim not to be able to produce and market precooked fonio without resorting to the external use of machines. 20 of them are recorded in Mali, 1 in Senegal.

Small enterprises
Small enterprise differ from micro-enterprises by the use of modern equipments (sifters, husking machines, gas or solar driers, etc.); their production capacity (higher than 10 tons a year); the independence of processing activities from the family level. They are three in Mali and only one in Senegalese (even if his annual production is only 6 tons, it is however well-equipped with 3 husking machines, a drier and has a permanent activity). These types of enterprises do not exist in Guinea.

2.4.1.2. Service providing enterprises

They are workshops equipped with one or more machines to husk and/or whiten the fonio. They are enterprises characterized by one main function: primary and secondary processing of fonio. They play an important role in the running of processing enterprises without husking machines. There are 2 of them in Bamako, 6 in Senegal and 13 in Guinea. While they are owned by individuals in Mali, they are still community properties in Senegal. In Guinea, most service providing enterprises are also community owned.

Cliché: O. Gueye (Enda)

Fig.39. Service providing workshop in Mali

In Mali, they were established to take advantage of business or technical opportunities. In Senegal, they were set up as part of a project aimed at boosting the production by overcoming bottlenecks, i.e. husking, while in Guinea village initiatives to address fonio husking was the starting point for the initiatives. The only individual service providing enterprise in Labe also benefited from the test of the CFC project and succeeded in bringing changes and diversifying machines other than fonio processing ones that enable it to strongly engage in the activity.

2.4.1.3. Fonio distribution enterprises

They are enterprises that actually do not process fonio, but rather sell it. They are specifically positioned at the level of distribution channels. As they specialized on other grains and sensed business opportunities in the fonio sector, these enterprises order precooked fonio from local or sub-regional enterprises, which they sell back, usually for export, under their own label together with other products. These enterprises are mainly found in Senegal. Eight of them have been identified so far.

2.4.1.4. Fonio processed by fonio MSEs

While Guinea is ranked as the main fonio producer, Mali is rather ranked first in the processing of new fonio products. Senegal imports precooked fonio from Mali to re-export to other countries. Senegal and Mali have produced and traded about 426 tons in 2006. The share of Senegal remains very low; not more than 10 tons, representing 2% of the total production. Mali produces 98% of the fonio produced by both countries. That production, calculated for 27 Malian MSEs, concerns about 416 tons of finished products, including 371 tons of precooked fonio, 7 tons of djouka, 2 tons of other by-products and 38 tons of semi-finished products, particularly whitened and washed-out fonio (by women along the Niger River in Bamako). As far as Senegal is concerned, it essentially produces precooked fonio. Apart from people engaged in the processing of fonio, Malian service providers husked and/or whitened 450 to 500 tons of fonio in 2006.

Those service providers receive fonio both from traders (semi-wholesalers and retailers), households, and fonio processing MSEs. About 51% of the fonio processed by MSEs, representing 212 tons transited (husked and whitened) through service providers.

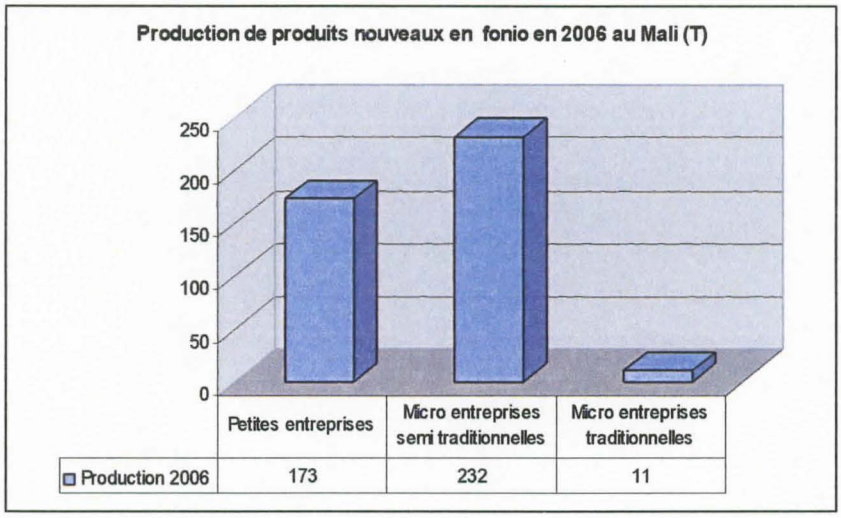


Fig.40. New fonio products commercialized by 27 MSEs in Mali

Fonio production is unequally distributed according to the type of enterprises. In Mali, 41% of processed fonio, representing 173 tons was produced by Small Enterprises (3), which constitute 10% of all the surveyed MSEs. Micro-enterprises, which represent 83% of all enterprises, had produced 243 tons of marketed finished fonio, representing 59%. That production is distributed as follows: 95%, representing 232 tons by semi-traditional micro-enterprises (20 MSEs) and only 5%, representing 10 tons by traditional micro-enterprises (4 MSEs).

In Senegal, 7 out of the 12 MSEs recorded did not realize production in 2006 and 55% of fonio production in 2006, i.e. 5.5 tons, was only produced by a single enterprise. The remaining production was realized by the 4 others. In Senegal, fonio production by enterprises remains very week and unsteady.

2.4.2. Jobs generated by fonio processing enterprises: fonio MSEs, female job generator

One has considered as "employee" any person working frequently within the enterprise and that is paid for that. They can have a monthly salary, at piece-rate pay or daily wages. The volunteer employees are not taken into account. Cleaning operatives realizing household works are not taken into account either. The activities in the fonio sector have encouraged the creation of over 330 direct jobs and over 1,000 indirect jobs in Senegal and Mali.

Female employments are largely predominant. Women hold 89% of the employments generated in the two countries, representing 295 women. Among them, seasonal employments are more important in number: 215 out 295, which are 73% of the jobs. Men only occupy 11% of the employments created, including 13 permanent positions and 22 seasonal workers. Senegal accounts for 32 jobs, including 5 men (2 permanent, 3 seasonal) and 27 seasonal women workers. These employments are unequally distributed in the two countries. 91% of the jobs (299) are in Mali and 9% in Senegal (31). The portion of men/women remains almost in the same order altogether.

Cliché: O. Gueye (Enda)

Fig.41. Women working at MSEs level in Mali

2.4.3. Fonio processing and marketing in Guinea

The issue of fonio is not a novelty. Apart from that mission, many studies were conducted on fonio in Guinea (Cruz-1996; PASAL/BCEPA-1999; Diallo-2001; Chaloub-2004; Cruz, Dramé & al-2004) as well as communications delivered (Diallo-2006).

2.4.3.1. Fonio moving from food crop to cash crop

There is a real dynamism in the marketing of husked fonio, whitened fonio, and washed-out fonio. Many stakeholders are investing in the marketing of fonio together with other grains. Fonio is the second grain traded on the market after rice. Although until recently, only husked fonio was dominant on the market, there is currently a real breakthrough of whitened and washed-out fonio. The paddy of fonio is only sold for rituals and other forms of sacrifices. Fonio is subject to particular attention among specialists of the sector. The circulation of fonio requires a well-organized network of various players, each representing a link of the chain (collectors, wholesales, retailers) with some organization and operating methods that urged to real ingenuity.

2.4.3.2. Funding and organizing the collection and re-distribution of fonio

The collection of fonio is done in many areas. The activity is undertaken by many collectors, who are working most of the time on behalf of wholesalers. Women are predominant in that activity area. One wholesaler can have up to 10 to 15 collectors working for them, or even more, and who live in different villages. One person in the group of collectors plays the role of go-between with the wholesaler. It is that person who receives the funding and shared it depending on the dynamism and capacity of each collector. The funding varies depending on the financial capacity of the wholesaler. A lady-wholesaler met on the weekly market of Miti (Fouta Djalon) stated that she distributes about 6 to 7 million Guinean Francs in times of high collection just after harvest, which is the equivalent of about 2.5 tons a week, while another wholesaler established in Labé (Fouta Djalon) distributes up to 10 million Guinean Francs in times of high collection, corresponding to 3.8 tons week.

The collection time depends basically on the season, which predisposes to the presence of fonio on the market. For example, the harvesting time for 20 tons of fonio varies from 1 to 3 months depending on whether collection is done after the harvesting ("Dabunde" cold dry period from December to February) or during the rainy seasons.

Very often, wholesalers either sell back directly to wholesalers in other countries of the region, or to another wholesaler who will sell back to wholesalers in other countries and to semi-wholesale dealers in charge of supplying retailers and local markets. A wholesaler in 2006 sold about 75 tons of whitened fonio, including 80% for the Gambian and Senegalese markets, while the remaining part was sold in Conakry. The same volume was distributed by 25 other wholesalers whom he supplied about 3 tons each per year. Women were the majority along the line, which comprised 5 men, about 20%.

As far as retailers are concerned, they prefer purchasing husked fonio very often on the closest markets before washing it, drying and then selling it.

Despite these examples that show the dynamism of the stakeholders, marketed volumes however remain very low in the major production regions, namely Upper Guinea and Middle Guinea.

2.4.3.3. Guinean fonio supplies most export markets

Guinea is the main supplying source of fonio for West Africa. Throughout well-organized trading networks the "Guinean" fonio, which at times has changed of identity, becoming rather "Senegalese or Malian", thanks to the export distributors, ended up consolidating its export market thanks to the dynamism of traders (wholesalers, collectors, retailers) reaching beyond bordering regions and local weekly rural markets.

Guinean fonio exports are sub-regional above all. The fonio is sold, first in the sub-region (Mali, Senegal, Gambia, Sierra Leone, Cote-d'Ivoire), and then to Europe (France, Belgium, etc.), the United States of America, etc. Exchanges between Guinea and the countries of the sub-region concern mainly husked fonio and whitened fonio, while the produce exported to France concerns mainly precooked white fonio and, to a lesser extent, toasted white fonio. Even though Guinean exports to France are still low in terms of volume, countries in the sub-region ensure the export of important volumes of fonio from Guinea to Europe and to the United-States.

2.4.3.4. Renewed interest for fonio with development of mechanization

The constraints after fonio harvesting have for long been detrimental to it on the benefit of rice, which urban dwellers have adopted. Rural dwellers in the major producing regions also followed in the footsteps of city dwellers for at least two reasons: giving up the hardness of fonio production, and showing their pride of modernity by having the same dietary habit as urban dwellers, which is rice. However, for a few years, fonio has entered cities and has become the main grain during outstanding events (family ceremonies, celebrations, food for important guests). Fonio has gone from a period of depreciation to a period of revival, i.e. a revolution of its image.

Despite the leadership position of Guinea for fonio production, the processing and marketing of finished and semi-finished fonio products is still tiny compared to Mali and Senegal. Fonio processing micro-enterprises are still at a starting point and precooked fonio (one of the major innovations of the past 15 years in the sub-region) remains mostly unknown to many Guineans. In recent years, production had even been declining, while on the other hand, public policies did not take it into account in laying down and supporting the levers of the Guinean economic levers. Today, a new discourse has emerged in favor of fonio. About thirty husking machines were set up in Labe, Kindia and in other villages (Diountou, Brouwal Kassa, Ley, Felo, Freya), and developed a growing sector of fonio husking and whitening service providers.

The hardness of post-harvest operations had constituted the main constraint that contributed to the progressive marginalization of fonio to the profit of more easily handled grains. The introduction of mechanization (mainly mechanic dehullers) has aroused major waves of changes in the relationship of people to the grain. It was noticed that the mechanization of husking has really unleashed the production in the places where this was experimented. The ongoing dissemination work (for GMBF dehuller) undertaken by the "Dynafiv" project should contribute to the recovery process of the grain.

Unfortunately, Guinea is not yet equipped with a wide network of qualified manufacturers who are capable of satisfying the specific needs of people, while keeping the costs under control. Many installations visited still suffer defects (due to unskilled technologists and machinists), which strongly reduce the profitability of the machines made available to the population.

2.4.4. Mechanization and innovation on fonio MSEs in Mali

The mechanization of husking and whitening of fonio enabled the sector to make a startling progress. Even though the dissemination of husking machines is still to be promoted for a better expansion, the existing ones operate at full capacity. 23 out 27 Malian MSEs are using husking machines. They are using them either within the enterprise (3 MSEs, i.e. 13%), or by resorting to external services (20 MSEs, i.e. 87%). In this way, 360 tons, i.e. 97% of processed and marketed fonio in Mali were husked and/whitened with machines. Out of that batch, external service providers hold an important part. 20 MSEs out of the 23 that are using machines services resort to external services, which represents 187 tons of fonio processed in 2006.

2.4.4.1. Impacts of mechanization and innovation on fonio MSEs in Mali

It is important to note that effects of mechanization and innovations in fonio enterprises appear at various levels:

At the organizational level

- ✓ Increase in qualified workforce for quality product processing resulting into an internal re-structuring within most advanced MSEs
- ✓ The development of new skills
- ✓ Re-definition and distribution of tasks
- ✓ Adjustment to the requirements of performance (hiring new technical personnel: accountant, secretary, servicing agents, production or marketing managers, etc.)

At the level of production

- ✓ Increase in the volume of marketed produce
- ✓ Measures to boost the production of other grains and African products for the Diaspora,
- ✓ The development of a local expertise in the sector,
- ✓ Alleviation of women's work
- ✓ Time gain
- ✓ New perception of the produce by households and people in general (change in mindsets)

At the level of supplies

- ✓ New partnership relations between suppliers and enterprise managers
- ✓ New forms of tacit of written contracts between suppliers and MSEs
- ✓ New plans and strategies to secure continuity in production

- ✓ More and more demand for quality from MSEs

At the level of marketing

Local markets

- ✓ More dynamism in local markets (Supermarkets, groceries, filling station shops, district shops, small keepers, households, etc.)
- ✓ Accessibility and increase in fonio consumption in urban households

Exports

- ✓ Opening and expansion of exports (5 to 20% of traditional and semi-traditional micro-enterprises and 50 to 85% of semi-industrial micro-enterprises)
- ✓ Capturing opportunities
- ✓ Increased added value on fonio
- ✓ The development of a Malian label (building a fonio brand image)

Marketing networks,

- ✓ Multiplication of networks
- ✓ Diversification of players and of the destination of products
- ✓ Diversification of business opportunities

At the level of relationships

- ✓ Strengthening and intensification of relationships for the construction of social and business solidarities.

In fighting poverty and social exclusion

- ✓ Self-employment and job creation (the development of new jobs and new skills)
- ✓ Restoration of self-confidence and dignity
- ✓ Plans for the perpetuation of activities and the desire to pass on the heritage to the youth
- ✓ Emergence of new female leadership
- ✓ Promotion of the image and products of Africa
- ✓ Spreading-out wealth

2.4.4.1. Opportunities and constraint for fonio MSEs in Mali

Opportunities

- ✓ An expanding market
- ✓ Support for innovation (research)
- ✓ Network creation
- ✓ Offer is lower than demand
- ✓ Recognized expertise in the processing activity at the national and international levels
- ✓ A niche for the creation of wealth

Constraints

The main constraints hampering fonio processing are the following, among others:

- ✓ The removal of sand from the fonio & fonio washing
- ✓ Command of the energy
- ✓ Deficit of equipments for about 80% of MSEs
- ✓ Inadequacy of working capital (stocks)
- ✓ Inadequate control of markets by Micro Enterprises (slow sales)
- ✓ Lack of loans to meet the offer (high interest rates)
- ✓ No consultation between fonio producing MSEs
- ✓ Prices are not homogenous: for instance, from one MSE to another, precooked fonio is sold 700, 750, 800, 850 FCFA
- ✓ Large margins between prices in MSEs and in Supermarkets: precooked fonio is sold 1000 FCFA (margins of 150 to 300 FCFA)

Deviations from the project workprogramme, and corrective actions taken

The deadline for deliverable 21 was adjourned in order to have time to finish the survey in Mali. To date, the results about Mali concerns only 30 MSEs out of 50 recorded. The final report will provide the opportunity to cover all of them.

List of deliverables, including due date and actual/foreseen submission date

Del. no.	Deliverable name	WP n°.	Date due	Actual/ Forecast delivery date	Estimated indicative person-months *)	Used indicative person-months *)	Lead contractor
21	Report on the typology of the SMEs involved in fonio processing	4	9	25			ENDA Graf
22	Report on the internal organisation and economic evaluation of the SMEs	4	24	25			ENDA Graf
23	Report on the supply and marketing systems of the SMEs and its potential and constraints for changes	4	25	30			ENDA Graf

List of milestones, including due date and actual/foreseen achievement date

Milestone no.	Milestone name	Work package no.	Date due	Actual/Forecast delivery date	Lead contractor
M4.1.	A typology of SMEs is available.	4	9	25	ENDA Graf
M4.2.	Intermediate workshops (month 6, 18 and 26)	4	6, 18, 26	Done in June 2006 Done in April 07 Done in October 07	ENDA Graf
M4.3.	A characterization of each type of SME is available in term of internal, supply and market organization.	4	24	25	ENDA Graf
M4.4	An assessment of the potential and constraints of each type of SME is available	4	25	30	ENDA Graf
M4.5	Final seminar	4	35	35	Cirad

2.5. Work package 5 - Opportunities for diversification and multipurpose uses of fonio in crop-livestock farming systems

Responsible scientist: Dr. Eric Vall – CIRDES (Burkina Faso)
Other participating contractors: IRAG (Guinea), IER (Mali), Cirad (France) and CRAW (Belgium)

Tasks	5.1. Analysis of diversity	5.2 Characterization of role of fonio in cropping systems	5.3 Analysis of production and prospective strategies	5.4 Characterization of socio-technical environment	5.5 Design of innovations
Year	2006	2007-2008	2007	2007	2007- 2008
CIRDES	E. Vall A. B Kanwé B. Daho	E. Vall A. B Kanwé B. Daho	E. Vall A. B Kanwé B. Daho	E. Vall A. B Kanwé Ms. N. Andrieu	E. Vall A. B Kanwé Ms. N. Andrieu
IRAG	F. Béavogui T. A. Diallo Ms. M. A K. Soumah	F. Béavogui T. A. Diallo	F. Béavogui T. A. Diallo	F. Béavogui T. A. Diallo	F. Béavogui T. A. Diallo
IER	D. Sogodogo	D. Sogodogo	D. Sogodogo	D. Sogodogo	D. Sogodogo
Cirad	P. Dugué	D. Richard P. Dugué			P. Dugué D. Richard
CRA-W	B. Dupuis	B. Dupuis	x	x	B. Dupuis

Workpackage objectives

WP5 general objective is to characterise, in the producing zones, the roles of the fonio in the farming systems, and it economic importance in food or feed systems.

The specific objectives are:

1. Analysis of the diversity of fonio based farming systems.
2. Characterization of the place of fonio inside the crop-livestock systems and the recent evolutions.
3. Analysis of the actual strategies and the prospective.
4. Characterization of the assets and constraints of the socio-technical and organisational environment.
5. Elaboration of schemes for the co conception of innovation processes.

Progress towards objectives – tasks worked on and achievements

The specific tasks for the reporting period were

- Task 5.1.: Analysis of the diversity of producers: Data analysis, writing of the final report (D24)
- Task 5.2.: Characterization of the place of fonio in the production systems and its evolution: Monitoring of the fonio land (technical route and measurement of the output), data analysis, and drafting of the final report (D25)
- Task 5.3.: Analysis of production strategies and evolution pathways: Surveys, data analysis and drafting of the final report/ratio (D26)
- Task 5.4.: Characterization of assets and constraints of the socio-technical environment: Survey, data analysis, and drafting of the final report/ratio (D27)
- Task 5.5.: Co-designing of innovations: setting up of multi-areas tests and follow up
- Common Activity WP5 and WP2: Test of fonio straw as foodstuff
- Common Activity WP5 and WP6: Common workshops of farming campaign before and after the rainy season (Bamako-Mali and Bobo Dioulasso – Burkina))

Major achievements during the reporting period (2007) are the following:

Task 5.1. Analysis of the diversity of producers

Data collected during the first year were analysed from November 2006 to January 2007. Then, the activity report was written to edit the deliverable D24 "*Rapport sur la typologie des systèmes de production, base de données, identification des zones prioritaires d'intervention*" in June 2007.

Task 5.2: Characterization of the place of fonio in the systems of production and its evolution

- Development of a collection of local varieties of fonio (November 2006 - January 2007)
- Development of monitoring forms (February 2007-March 2007)
- Monitoring of the fonio lands, and of the preparation of harvest (April 2007 - November 2007)
- Data analysis (December 2007)
- The final activity report is scheduled for February 2008:

Task 5.3: Analysis of the strategies of production and evolution pathways

Questionnaire drawing up on February 2007, survey implementation on May 2007, data Analysis on Aug/Sept. 2007 and report writing on Oct/Nov. 2007.

Task 5.4: Characterization of the assets and constraints of the Socio-technical environment

Questionnaire drawing up on February 2007, survey implementation on June/July 2007, data Analysis on Aug/Sept. 2007 and report drafting on Oct/Nov. 2007.

Task 5.5.: Co-designing of innovations

Setting up of the multi – areas tests and monitoring (April 2007-November 2007)

Common Activity WP5 and WP2: Test of fonio straw as foodstuff

Protocol drawing up (May 2007), production of fonio straw in station (June to October 2007) and feeding tests (from November 2007 to January 2008). Data Analysis and report writing are scheduled from February 2008:

Common Activity WP5 and WP6: Common Workshops

Participation in the WP6 meeting in Bamako to prepare the 2007 farming campaign (April 2007)
Organization of the WP5&6 "post-rainy season" meeting in Burkina Faso (October 2007)

2.5.1. Analysis of the diversity of producers (task 5.1.)

Methodology

- Sample of 300 fonio producers in the main zones of fonio production
- Survey on the characteristics of the production systems, place, role and farming of fonio
- Data Analysis by agro-ecological zones and constitution
- Implementation of a typology according to the agro-climatic zones
- Analysis of the place of fonio in the systems of production of each type
- Analysis of the farming methods of fonio in each type

Major results

The map below shows the various agro-climatic zones surveyed by WP5

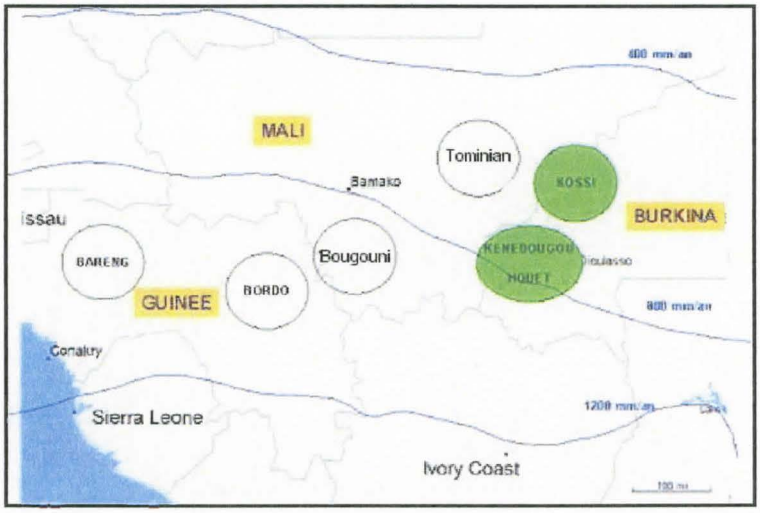


Fig.42. The agro-climatic zones surveyed by WP5

Table below shows the general characteristics of the production units surveyed in the various agro-climatic zones.

Agro-ecological zones	**Semi-arid zone**		**Sub-wet zone**			**Wet zone**	**Average**
Countries	Burkina	Mali	Burkina	Mali	Guinea	Guinea	
Zones by country	Kossi Zone	Tominian Zone	Kénédougou -Houet zone	Bougouni Zone	Bordo Zone	Bareng Zone	
Age of exploitation chief (years)	48	54	48	Nd	53	62	49
Year of settling in of PU chief	1989	1985	1986	Nd	1956	1944	1973
Number of household /PU	2	2	2	Nd	1	2	2
Number of persons to feed/PU	16	15	15	Nd	13	12	14
Number of workers /PU (wkr)	9	12	8	Nd	6	7	7
Total Cultivated surface /PU (ha)	12	11	9	Nd	6	6	9
Total Cultivated surface /workers/PU (ha)	1.7	1.0	1.4	Nd	1.0	0.8	1.1
Units of Cattle Tropical/PU (UBT)	15	12	6	Nd	11	6	10

Caption: PU (Production Unit), UBT (Unité de Bétail Tropical = 205 kg), Nd: non given data

Table20. Characteristics of the production units in the various agro-climatic zones

On the whole zones, the production units are of big size with an average of 2 households by PU (Production Unit) rand 14 mouths to be fed. The fonio is mainly intended for family subsistence farming. The quantities of fonio sold are marginal and aims at the satisfaction of small financial needs. The large majority of the fonio lands are managed by men, but in approximately 7% of the agricultural households, the women have their own fonio lands. In Kotoudéni (a village located at 15 km from Orodara in Burkina Faso), women produce fonio with the objective to sell it at the market of Orodara.

In semi-arid zone, the fonio is integrated in a mix farming system: traditional cereals and breeding, and plays a key role in the food safety of the households (between September and November). The production units are of a bigger size than the average (number of actors, surface cultivated, and livestock). The share for breeding is more significant than in the other zones. The food insecurity is more severe which leads to significant purchases of cereals.
In the sub-humid zone, the fonio is integrated in a much diversified mix system composed of cereals – tubers - arboriculture. Its share in the rotation is higher. The production units are of more moderate size and the place of the breeding seems more limited
In the wetland, the production units are more moderate than in the other zones, the place of breeding is limited.

Figure below shows the place of fonio in the rotations.

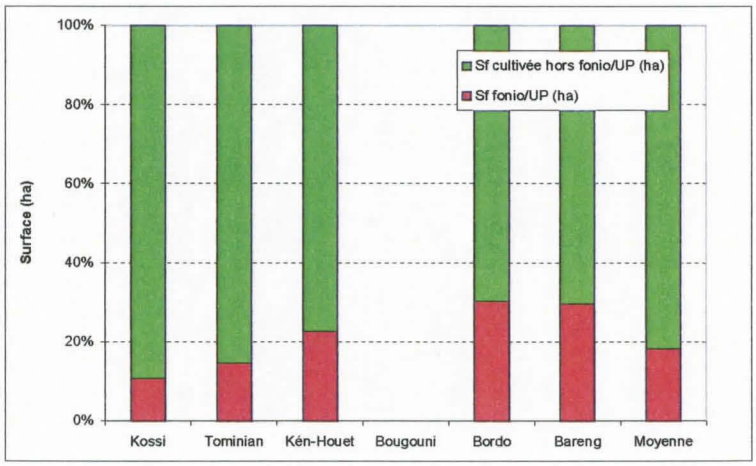


Fig.43. Place of fonio in the rotation of the various agro-climatic zones

Analysis of cultivation methods of the fonio in each type

In the semi-arid zones of monotonous relief, the fonio is cultivated on sandy grounds. In the sub-humid and wet zones, it is cultivated on plains but also on the slopes (thus also on gravel ground). Today the ground is mainly tilled with the plough but in some places the manual hoeing remains a current practice.

The seeds are definitely earlier in the sub- humid zones and later in semi-arid zones. On the other hand, in Mid Guinea the sowing of the fonio is as late as its harvest. The quantity of seeds per hectare is close to 30-40 kg (it is higher on the fields cultivated with the plough). The fonio is weeded once manually, sometimes twice in more rainy zones. It does not need any fertiliser. Its principal enemies are the striga and the adventitious weeds.

The harvest takes place in the second week of September. The reaping and threshing of fonio are labour intensive operations accomplished through collective labour. The output of the fonio would lie between 500 and 700 kg/ha. It is then threshed with stick (or pressed with the feet) to get the paddy grain. It is finally decorticated manually with the pestle. The threshing is usually a men activity whereas processing (dehulling and whitening) a women activity. These two post-harvest operations are very demanding in labour. So they strongly contribute to increase the price of fonio on the market compared to other cereals. The mechanization of its operations could contribute to decrease the price of fonio and to reinforce its competitiveness on the local market.

Agro-ecological zones	Semi-arid Zones		Sub-wet zone			Wetland	Average
Countries	Burkina	Mali	Burkina	Mali	Guinea	Guinea	
Zones by country	Kossi Zone	Tominian Zone	Kén-Hoe Zone	Bougouni Zone	Bordo Zone	Bareng Zone	Average
Nb of fonio farmland	1.2	1.0	1.4	nd	1.9	1.7	1.4
Area fonio PU (ha)	1.3	1.5	2.3	nd	1.4	1.1	1.5
Farm Age (years)	17	26	9	5	6	5	11
Fonio/ plain (%)	96%	82%	64%	56%	12%	45%	59%
Ploughing by animal haulage (plough)	89%	100%	60%	68%	90%	63%	78%
Average date of the fonio sowing	1-June-06	28-May-06	5-May-06	15-May-06	10-May-06	1-Jul.-06	25-May-06
Seed rate (kg/ha)	29	37	38	35	30	25	32
Weeding numbers	0.6	1.0	1.1	1.6	1.0	1.0	1.1
Average date of fonio reaping	17-Sept.-06	21-Sept.-06	22-Sept.-06	25-Sept.-06	5-Sept.-06	10-Nov.-06	26-Sept.-06
Interval sowing-reaping (days)	108	100	140	115	118	132	119
Reaping lasted (Days/act/ha)	29	18	40	nd	41	45	35
%PU practitioner threshing with stick	53%	58%	100%	25%	100%	100%	73%
Threshing duration /act/ D/ha/act)	27	nd	35	nd	16	39	29
Fonio Production (kg/PU)	827	699	1717	nd	702	547	898
Fonio yield (kg/ha)	594	698	688	378	596	467	570

Table21. Characteristics of the technical routes of the fonio in the various agro-climatic zones

2.5.2. Characterization of the place of the fonio in the production systems and evolution (task 5.2)

Methodology

- Monitoring of the cultivation methods on 60 farmlands of fonio (20 lands monitored by country at a rate of 10 fields per village (1 village by production zone)
- Development of the monitoring sheets in May and June 2007
- Identification of the producers and farmlands in May and June 2007
- Monitoring of the fields from cultivation to harvest (recording of the farming operations, monitoring of the state of the crops and measurement of the output); records of the observations on 5 pieces of land of the farm by field.

Major results

On the date of drafting of this report, only the data from Burkina zone are available. They were collected in 4 villages: Soin and Simbadougou in the northern zone (Kossi province) and Kourynion and Kotoudéni in the southern zone (Kenedougou province) at a rate of 5 producers per village. Table below indicates the major elements of the technical routes in these two zones (dates and methods of the farming operations, production, working time and expenses per ha)

Unit	Northern Zone	Southern Zone	Average
DATES			
Date of ploughing	27- June	19- May	08- June
Date of sowing	27- June	19- May	08- June
Date of Re-sowing		10- June	10- June
Date of lifting	2-Jul.	09- June	21- June
Date of weeding	24-Jul.	9-Jul.	17-Jul.
Date of reaping	30-Sept.	29-Sept.	29-Sept.
Date of threshing	12-Oct.	14-Oct.	13-Oct.
TECHNICAL OPERATIONS			
Mechanical ploughing with the plough	100%	78%	89%
Seed rate (kg/ha)	29,8	43,2	36,2
Striga (% infestation)	11%	15%	13%
Adventitious (average covering %)	19%	18%	18%
Number of weeding	1	1	1
Drying duration after reaping (Day)	31.1	17.9	28
PRODUCTION			
Yield paddy grain(kg/ha)	609.1	627.7	617.9
Yield straw cut (kg/ha)	671.9	985.6	820.5
Red sorrel (plant/ha)	4 767	3 241	4 044
EXPENDITURE (Fcfa)			
Expenditure for seeds	0	489	232
Expenditure for ploughing	600	4 642	2 515
Expenditure for reaping	1 285	3 820	2 553
Expenditure for threshing	553	10 170	5 108
WORKING TIME			
Ploughing duration (D/ha/act)	8.9	10	9.4
Weeding duration (D/ha/act)	3.4	8.5	5.8
Reaping duration (D/ha/act)	19.7	20.1	19.9
Threshing duration (D/ha/act)	21.3	15.7	18.7

Table22. Technical route of the fonio according to geographical areas

The sowing was earlier in the south, but in the two zones the harvest was carried out during the same period which tends to confirm the sensitivity of the varieties of fonio to a photoperiodic system. In the South, a relatively significant share of the fields was prepared manually before the starting of the rains and a part of the fonio was sown in dryness. The delay of the rains delayed the lifting of the seeds in the

southern zone and constrained many producers to sow anew, which explains the higher amount of seeds in the southern zone. In the two zones the invasion of the fields by the striga and the weeds was overall the same. The fonio does not receive any chemical input (herbicides, manure...), the rare fertilizer contributions being made in the form of organic manure. It is possible to qualify it as traditional biological farming which is an asset to be preserved and to develop on the Bio market.

The output is slightly higher in the southern zone. But this year was characterized by a bad rainfall in the sub-wet zones and good in the semi-arid zones (despites some floods), which can explain the good results in the northern zone. In the north the peasants would tend to reap the fonio higher with smaller a sickle, which explains the low output of straw in this zone. However, the valorisation of the straw is more significant in north in particular in the form of fodder in dry season. Also, it seems paradoxical to cut the straw of fonio higher in this zone (the practice of threshing with feet at home being very common in the north, could justify this practice intending to limit the efforts of transport from the field to the house). The rooted straw of fonio remaining in the field after reaping is about 3 tons of dry matter per hectare which favours a good coverage of the ground in dry season and represents for the livestock a resource of pasture in dry season.

In the north, the expenses for the culture of fonio are very low. In the south the expenses are significantly higher for women producers because of the fact of hiring animal-drawn plough and resorting to extra manual labour for reaping, and especially the threshing which requires a significant labour force, thus requiring much external assistance to avoid the rotting of harvest in the field. The reaping and threshing are the two most demanding farming operations in working times. To that, must be add the processing (dehulling). These two manual operations strongly contribute to the rise in the price of the decorticated fonio. Thus, to reinforce the competitiveness of fonio on the local market, it would be advisable to develop the mechanization of these operations in the villages and particularly for primary processors.

According to some carried out measurements, it arises that 4 main factors affect the output of fonio. There is first, the age of the field (duration of the field being used as farm without fallow). The older the field, the less output is obtained. This can be explained by a decrease of fertility in the fields subjected to a continuous farming for many years.

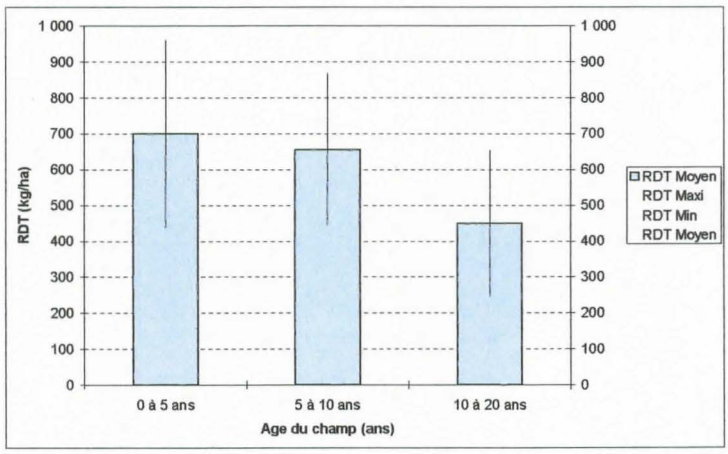


Fig.44. Output of fonio paddy according to the age of the field

In the second place, there is the organic manure contribution. The majority of the fields of fonio do not receive organic manure because the farmers think that this practice is not useful for a crop that accommodates to poor grounds. Some producers do contributions of organic manure in the form of faecal manure deposit in the field: either during animal divagation at grazing time (limited contributions), or by organizing a night-parking of the herd on the field (a more significant contribution). Figure below indicates that the organic manure has a positive effect on the output of fonio.

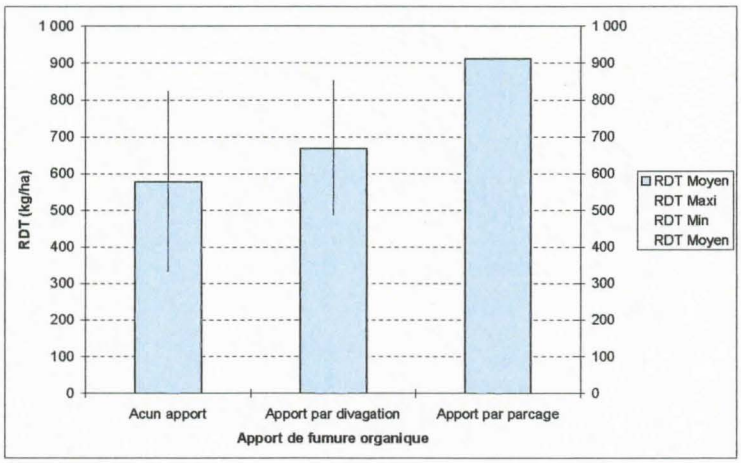


Fig.45. Output of fonio paddy according to the organic manure contribution

In third place, there is the effect of weeds. By competing for water and nutriments the adventitious weeds affect negatively the output of fonio. This effect was observed on the sample fields.

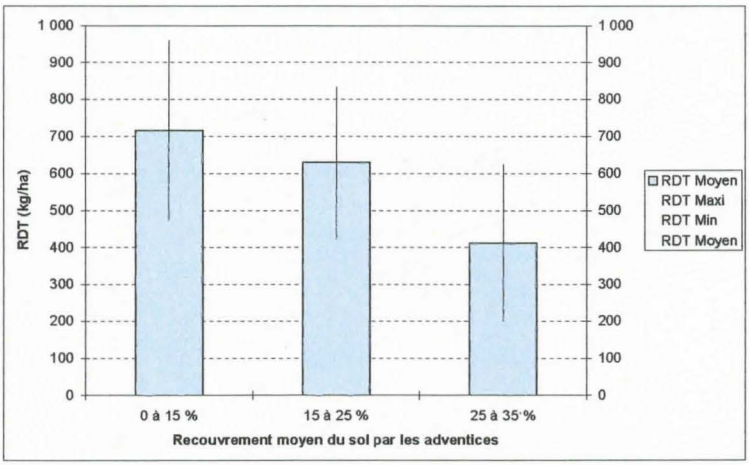


Fig.46. Output of fonio paddy according to the average level of weed coverage

Lastly, there is the quality of the weeding. The earlier the weeding is, but repeated as well, the more controlled is the level of weeds on the fields; which has a positive effect on the output. This is why the output is higher on the fields subjected to early weeding.

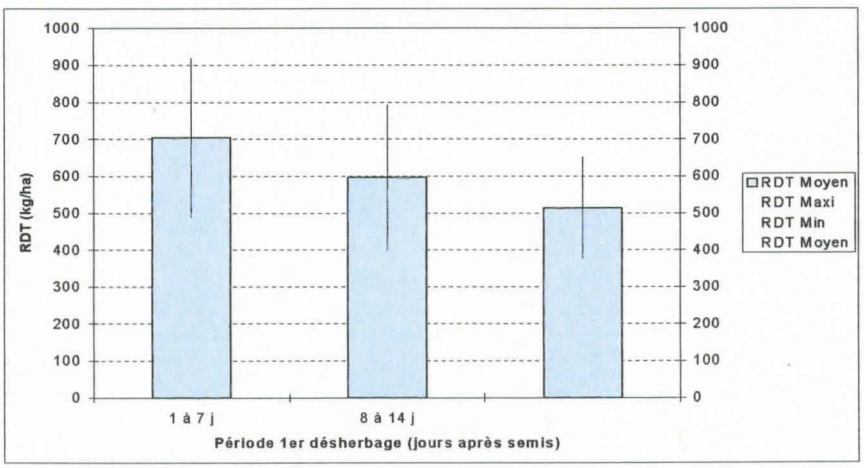


Fig.47. Output of grain paddy according to the precocity of the weeding

2.5.3. Analysis of strategies of production and evolution pathways (task 5.3.)

- Implementation of survey during the second semester of 2007
- This activity is now coordinated by Ms. Nadine Andrieu (agronomist at Cirad, now at CIRDES since April 2007).
- Survey work is underway. The final report will be delivered in April 2008.

2.5.4. Characterization of the assets and constraints of the Socio-technical environment (task 5.4)

- Implementation of planned surveys in the second semester of 2007
- This activity is coordinated by Ms Nadine Andrieu
- Survey work is underway. The final report will be delivered in April 2008.

2.5.5. Co-designing of innovations (task 5.5)

This activity was postponed for the year 2008. It will include two types of experiments:

- 1) Valorisation of the straws of fonio during the dry season 2007-08: for the fertilization (tests of composting of fonio straw especially in the exploitations of the southern zone which values less this biomass presently) and fodder valorisation (straw of fonio treated with urea in the semi-arid zones using traditionally the straw of fonio as fodder)
- 2) Improvement of the productivity of the fonio through a reasonable intensification during the rainy season 2008 with tests: varieties (valorisation of local productive varieties), and application of organic manure.

2.5.6. Activity common WP5 and WP2: Test of fonio straw as foodstuff

- Preparation of the test (July to December 2007) at the CIRDES station of Banankélédage: constitution of a stock of straw, preparation of the cages of digestibility and for animals
- Recruiting an agronomist at the end of 2007

2.5.7. Common Activity WP5 and WP6: Common workshops

- April 2007: Workshop in Bamako (Mali) to prepare the 2007 farming campaign finalization of the protocols
- October 2007: "Post rainy season" WP5&6 Meeting in Bobo-Dioulasso (Burkina): overview of 2007 activities and preparation of the valorisation of the results (reports, deliverables, publications…)

Deviations from the project work program, and corrective actions taken

For the task 5.1. concerning the analysis of diversity of the producers, it was decided to delay the deliverable D24 from March to December 2007 in order to integrate the results of the surveys carried out during the 2007 campaign.

For the task 5.2. the data analyses were delayed because of late harvest. For the 3 countries, the work will be completed in January 2008.

Tasks 5.3 and 5.4 were mainly conducted by a PhD student (Bakary Daho) involved in the design, implementation, analysis and reporting of the different studies. Tragically, this young collaborator is deceased in a road accident in September 2007. These activities are now coordinated by Ms. Nadine Andrieu (Cirad agronomist working at CIRDES since April 2007).

The task 5.5. "Co-designing of innovations" is postponed in 2008 whereas identification of constraints to overcome was completed in 2007.

List of deliverables, including due date and actual/foreseen submission date

Del N°.	Deliverable name	WP N°.	Date due	Actual/ Forecast delivery date	Estimated indicative person-months *)	Used indicative person-months *)	Lead contractor
24	Report on production systems typologies, databases, identification of priority zones for intervention	5	12	23	15	12	CIRDES
25	Report - Place of fonio in the whole farming system, priorities to strengthen the place of fonio in the household economy	5	21	25	12	0	CIRDES
26	Farmer's strategies and condition to improve the use of fonio as a diversification process	5	21	26	3	0	CIRDES
27	Report - Assessment of the socio-technical environment of the farmers producing fonio : conditions for supporting the emergence of professional organization « fonio » and improving the services	5	25	26	3	0	CIRDES
28	Activities plan : options for the development of fonio production and the improvement of the productivity and competitiveness	5	26	34	3	0	CIRDES
29	Dissemination of knowledge obtained into the project: publication of technical information, intervillages visits, papers for newspapers and audiovisual presentations	5	33	34	12	0	CIRDES
30	Scientific articles and communications in international conferences	5	35	34	3	0	CIRDES

Justification of putting off deliverable deliverance

Deliverable 24: delay due to lack of data at the end of the first reporting period. Data analyses were done in 2007 and the deliverable D24 is now available

Deliverable 25: delay due to late harvests of the fonio, affecting the processing of the data and the writing of the reports

Deliverable 26 and 27: delay due to late harvests of the fonio, affecting the processing of the data and the writing of the reports

Deliverable 28: Identification of the constraints preliminary necessary to the start-up of experiments in countryside, completed in October 2007

List of milestones, including due date and actual/foreseen achievement date

Milestone no.	Milestone name	WP n°.	Date due	Actual/Forecast delivery date	Lead contractor
M5.1.	Start up Workshop: planning, general methodology and WP5 workplan (m1 –m4).	7-5	1	Done in March 06	Cirad and CIRDES
M5.2.	Typologies and report: data collection (4mths) , database building multivariate analyses (3 months) workshop (month 13).	5-6	12 13	Done in Nov 07 Done in Nov 06	CIRDES
M5.3.	Parallel cases studies (place of fonio, farmer's strategies socio-tech and organisational environment) (months 3-23)	5	23	Scheduled 27	CIRDES
M5.4.	Consolidation of the diagnostic phase results - Workshop – (month 25)	5	25	Done in October 07	CIRDES
M5.5.	Co-conception of innovation: evaluation of the processes in narrow partnership with the farmer's organisation and the other stakeholder in the socio-technical environment.	5	25	Scheduled 33	CIRDES
M5.6.	Final seminar month 35	7	35	35	Cirad and IER

2.6. Work package 6 - Improving knowledge on fonio based cropping systems and ways for improving productivity.

Responsible scientist: Dr. Didier Stilmant – CRAW (Belgium)
Staff of the CRAW (Farming systems section) from Belgium is leading the Work Package 6 in close cooperation with Cirad (France).
Other participating contractors: IRAG (Guinea), IER (Mali), CIRDES (Burkina) and Cirad (France)

The different scientists involved are the followings

Participant n°	1	3	4	5	6
Organisation name	Cirad	CRA-W	IER	IRAG	CIRDES
Country	France	Belgium	Mali	Guinea	Burkina
Staff	**F. Forest**	**D. Stilmant** B. Dupuis	M.D. Sanogo D. Guindo M. Vaksmann	T.A. Diallo N'F. Cissé M. Camara M. Doumbouya A. Sané G. Niéba J. Gigou	E. Vall B.A. Kanwe

Workpackage objectives and specific objectives of reporting period

The general aim of WP6 is to improve the existing knowledge on fonio based cropping systems and ways for improving their productivity with attractive socio economical and environmental benefits and in phases with the market chain expectations. This had led to the definition of the following specific objectives:

1- Better knowledge on fonio varieties (morphologic diversity, genetic functioning, photoperiodism, cycle duration...) and capacity building for seed production and conservation meeting the needs of the different WP of the project and its follow up.

2 - Climate- soil- nutrients -biomass potential and efficiency analysis: Potential production of biomass for collected varieties depending on climate and nutrients resources. In situ flux study, water and nutrients balance for representative ecosystems.

3 - Present Fonio based Cropping System diagnosis: rapid survey of existing cropping systems and practices and analysis of actual biophysical performances under farmers conditions (link with WP5). Comparison of actual productivity with potential.

4 - Close the gap through innovation: To identify with farmers the desirable experiments aiming at increasing the resiliency of the cropping system (water nutrient efficiency, higher productivity, externality control)

The specific objectives of the reporting period were:

- To compile, to analyse and to synthesize the results from the field campaign 2006 and to confirm them through the implementation of multi-local varieties comparison trials in two Guinean sites and two Malian sites, this in order to cover wider pedo-climatic conditions.
- To define Fonio response to abiotic factors such as soil nutrients content and to photoperiod variation, also to complete 2006 results.
- To characterise the 42 Fonio varieties collected, in 2006, in the different villages, from Guinea, Mali and Burkina Faso, followed up by the WP5. These varieties are characterised from a morphological, technological (in collaboration with the WP1) and biochemical point of view.
- Based on these results, to propose innovation schemes to the producers for the 2008 rainy season.

Progress towards objectives – tasks worked on and achievements

2.6.1. Varietal characterisation (task 6.1)

2.6.1.1 Farmer characterisation of the most popular fonio varieties

This task was done according to usual farmer management and ecoregional zonation taking account for rain, soil and altitude constraints in Guinea and Mali. The 42 varieties collected in Guinea, Mali and Burkina Faso are now under characterisation through the definition of their technological use value, by the WP1, and through the definition of their biochemical and botanical parameters (figure below), by the WP6. These 42 varieties collected in the villages followed up by the WP5, were implanted in IRAG Centre of Bareng (Guinea) to perform their botanical characterization

Cliché : T. A. Diallo (IRAG)

Fig.48. Implantation of the 42 Fonio varieties in Bareng (Guinea)

Photo en végétation

FONIO

Photo du grain

Fonio variety description

Fiche Technique: descripteur fonio

I - Identification

Variété: espèce...*Digitaria exilis*.....
Nom vernaculaire.....
Signification locale du nom.....
Origine géographique (coordonnées GPS).....
Origine génétique....Locale.....

II - Caractère de la plante

Phénologie: levée .....jrs
Montaison .....jrs
Floraison .....jrs
Anthèse .....jrs
Maturation (cycle) .....jrs ou mois

Biométrie: hauteur des tiges à la floraison.....

III - Caractère des panicules

Aspect des panicules à maturité: dressé / retombant.....
Coloration des panicules : Blanche / violacé.....
Structure du racème : Nbr. ramifications.....
Longueur des doigts (en cm) .....
Nombre de rangées de grains par racème.....
Nbr. de grains/10 cm doigt.....
Sensibilité à l'égrenage : oui/non

IV - Caractère du grain

Aspect du grain: Aristé (Barbe) / Pilosité / Lisse....
Couleur des grains (Voir s'il existe une charte de couleur botanique à ce niveau, échelle mil ?).....
Forme (rond, allongé, dos de tortue, ...) .....
Longueur du grain.....Diamètre.....
Poids de 1000 grains .....

V - Caractère agronomique

Production de matière sèche de la plante entière.....kg/ha
Rendement potentiel en paddy (après battage et vannage) .....kg/ha
Sensibilité à la verse à maturité (faible ; moyenne ; forte).....
Sensibilité aux maladies/insectes (préciser à quoi et le niveau : Faible ; moyenne ; forte).....

VI - Qualités technologiques, culinaires et commerciales

**** Analyse technologique et organoleptique***

Taux de décorticage.....%
Rendement au décorticage (Décortiqué/Paddy).....%
Rendement blanchiment (Blanchi/Décortiqué).....%
Taux de brisure (Tamis 0,5 mm/Total blanchi).....%
Couleur du péricarpe (charte de couleur ?).....
Temps de cuisson.....
Texture.....
Gonflement .....
Goût.....

**** Analyse physico chimique sur décortiqué***

Matière sèche.....%
Cendres .....%
Lipides .....%
Protéines .....%
Glucides .....%
Amylose .....%

**** Analyse physico chimique sur blanchi***

Matière sèche.....%
Cendres .....%
Lipides .....%
Protéines .....%
Glucides .....%
Amylose .....%

Les chercheurs

Fig.48b. Fonio variety description form

2.6.1.2. Multilocal experiments

The collect of these most popular fonio varieties was done in Guinea and comparison in on-station and multilocal experiments was implemented in Guinea and Mali for agro morphological characteristics, yield (grain and fodder) and farmers evaluation.

Results from 2006 Guinean trials

Guinean trials included 13 varieties. Twelve were collected in representative villages from Bordo (Upper Guinea) and Bareng (Fouta Djalon) areas. The 13th variety came from Burkina Faso (CVF401) and is an early heading variety.

Varieties	Village	Farmer	Cycle length (farmer knowledge)
Bérélimbé (ou *Bérélengbé)*	Kassa	Djoumé Sidibé	3 months
Boléfondé	Doumba/pita	Alpha yagouba	4 months
CVF401	CRA/Bareng	T A Diallo	3 months
Dalaman	Tintioulinkoro	Mamady Kourouma	4 months
Fonibagbé	Balandou	Mory Diakité	4 months
Gbélen	Djénémarena	Wassamory Doumbouya	3 months
Kélianigbé	Tintioulenkoro	Laye Fodéba Kourouma	3 months
Kokounin	Tintioulenkoro	Mamady Doumbouya	4 months
Konso	Moron (Labé)	Koumba Tenin	4 months
Sirafing	Hindè/Labé	Mamoudou	3,5 months
Siragbè	Dalen/Labé	Amadou Siddy	4 months
Sitafa noir	Sigon/Mali	Modi oury	4 months
Sitafa rouge	Sigon/Mali	Samba foula	3,5 months

Table23. The 13 varieties tested in Guinea

These 13 varieties were compared in Bordo and Bareng trials implanted, respectively, the 24 of June and the 12 of July.

In these trials, the variety had a significant impact on the emergence rate ($p < 0.001$): on both sites *Sitafa Noir* and *Kélianigbé* emergence were, respectively, quoted 3.3 and 2.0, on a 1 (very bad emergence rate) to 5 (very good and uniform emergence rate) scale. This was probably link to poor seeds quality more than to intrinsic variety characteristic, underlining problem of seed stock renewing and conservation under field conditions.

Plant height, at the 50 % flowering stage, was significantly ($p<0.001$) influenced by the variety both at Bareng and Bordo. Mean heights were respectively of 61 cm and 54 cm, with a marginally significant correlation between the heights recorded in both these sites ($r = 0.529$; $N = 13$). At Bordo, two groups of varieties could be clearly distinguished : the short ones with an early heading date of 65 days (*Gbélen, CVF401, Bérélimbé, Kökounin, Kélianigbé, Dalaman* and *Fonibagbé*) and the taller ones, with a later heading date of 80 days (*Bolèfondè, Konso, Sirafin, Siragué, Sitafa noir* and *Sitafa rouge*). At Bareng, the discrimination, on the basis of plant height, was less clear with the varieties CVF401, *Bérélimbé, Kélianigbé, Siragué* making an intermediate group and *Sitafa Noir* shifting in the group with the shorter varieties.
Now, there was a very highly significant correlation of the heading dates in both sites ($R^2=0.932$; $N=13$).

Mean grain yields were of 780 kg/ha (835 kg/ha without *Sitafa Noir* that produced only 124 kg/ha at Bareng) and 788 kg/ha respectively at Bareng and Bordo. At Bareng, early heading varieties reached higher yields (952 kg/ha) than late heading ones (672 kg/ha without *Sitafa Noir*) ($p<0.001$), and this in spite of a global level of precipitation of 1150 mm uniformly distributed on 81 days from June to October. A possible explanation of these lowest performances could be the pressure exerted by a disease, under analysis, leading to a rapid plant desiccation. This pressure was very high on *Sitafa Noir* but was also observed, at a lower level, on other late heading varieties. On the other hand, no significant difference was observed at Bordo ($p>0.10$).

Var	Cycle	Kg/ha	% (mean of the corresponding group)
CVF401	Early	689,9	78,8%
Fonibagbé*	Early	826,2	94,4%
Kélianigbé*	Early	840,6	96,0%
Dalaman*	Early	864,8	98,8%
Bérélimbé	Early	873,5	99,8%
Gbélen*	Early	968,2	110,6%
Kökounin*	Early	1063,3	121,5%
Sitafa Noir	Late	390,9	53,1%
Bolèfondè*	Late	631,2	85,8%
Sirafin	Late	692,2	94,1%
Sitafa Rouge	Late	729,7	99,2%
Konso*	Late	777,6	105,7%
Siragué*	Late	848,9	115,4%

* variety included in the multi-local varieties comparison trials set up in 2007

Table24. Average yields observed in the two Guinean trials performed in 2006.

In average, *Gbélen* and *Kökounin* had very good performance in the early heading group while *Konso* and *Siragué* had the best performances in the late heading group.

Results from 2006 Malian trial

Malian trial, located in Cinzana IER Centre, near Ségou, included 5 early heading varieties (60 days) identified in a preceding CFC project: four Malian varieties (*Pon de Madougou*, *Pon de Boré*, *Local of Niatia* and another "Control" from Cinzana area).

No significant difference was observed between these varieties neither in terms of emergence rate (p=0.44), of plant height (p=0.70) nor in term of grain yield (p=0.12). Grain yield that was, in average, of 922 kg/ha with a fertilization rate of 30 kg of N/ha. *Pon de Boré,* "Control" from Cinzana area and *Local of Niatia* had the best performance, however the low yield of CVF477 and *Pon de Madougou* could be linked to a lower seed lot quality as these seeds, as *Pon de Boré* ones, were conserved two years before to be re-used. So they were included once again in the 2007 variety trials.

Variety	Grain Yield (kg/ha)	% of the mean
CVF477*	700.0	75.3
Pon de Madougou*	826.7	88.9
Pon de Boré*	988.9	106.4
Control from Cinzana area	1000.0	107.6
Local from Niatia*	1133.3	121.9

* variety included in the multi-local varieties comparison trials set up in 2007

Table25. Means grain yields observed in Cinzana trial performed in 2006.

Multi-local varieties comparison trials set up in 2007

Varieties comparisons, including the varieties quoted with an asterisk (*) in the tables above and *Finiba*, a late heading Malian, were performed in 4 sites: Bareng and Bordo IRAG Centres in Guinea and Cinzana and N'Tarla IER Centres in Mali.

A good emergence rate and distribution of the precipitations allowed a homogeneous development of the vegetation in Bareng and Bordo (figures below). This trial was implanted the 12 July 2007 in Bareng and the 6 July 2007 in Bordo.

Cliché : T. A. Diallo (IRAG)

Fig.49. Fonio varieties comparison trial from Bareng, 45 days after its implantation

Cliché : N. Cissé. (IRAG)

Fig.50. Fonio varieties comparison trial in Bordo, at the flowering stage of the early heading varieties

In Malian IER Centres, Cinzana and N'Tarla, the precipitations were more erratic and intense with, some days, more than 100 mm of rain. So the rainy season really started at the end of July to last only 45 days. This led to the establishment of lower population densities (Figure below). In Cinzana, the trial came after one crop of "niébé" (cowpea) itself preceded by one crop of Millet. The trial was implanted the 3 July 2007

Cliché: B. Dupuis (CRAW)

Fig.51. Fonio varieties comparison trial in Cinzana, after the harvest of the early heading varieties

In N'Tarla the cover was also less homogeneous (figure below) following the huge occurrence of the weed '*Borelia verticiliata*' that seems to be characteristic of poor soils (this hypothesis will be tested in performing a soil analysis). Nevertheless, this trial came after two years of fallow. This trial was implanted the 12 July 2007. In order to be able to take this heterogeneity into account in the analysis a quotation of the proportion of each parcel covered by this weed was required during the trial field visit performed in October.

Cliché: B. Dupuis (CRAW)

Fig.52. Fonio varieties comparison trial in N'Tarla, after the harvest of the early heading varieties

As on the late heading varieties in Bareng, in 2006, some areas characterized by sward desiccation, were observed on N'Tarla trial in 2007 (figure below). Is it due to some diseases or physiological stress? A special attention has to be paid to this problem in the future.

Cliché: B. Dupuis (CRAW)

Fig.53. Occurrence of sward desiccation in some plots in N'Tarla

All the rough data of these trials will be compiled for the 15 of January 2008 in order to be analyzed and published in a contribution aiming to test 'variety environment' interactions.

2.6.1.3 Providing grain and fodder samples to WP1 and WP2 for technological and nutritional analyses and to WP6 for on field experimentations
Running task.

2.6.2. Climate soil resources assessment in relation with fonio potential in Guinea and Mali (task 6.2)

2.6.2.1. Response to the photoperiod

Response of crop species to photoperiod allows them to be adapted to their environment in synchronizing their physiological state to climatic conditions under natural conditions, without irrigation. Such a response allows flowering grouping under good climatic conditions, whatever the sowing date and, so, to reduce mould risk associated to early flowering or water stress associated to late flowering. So the definition of fonio varieties response to photoperiod will characterize their adaptability/plasticity face to environmental variations and their sensitivity to the sowing date (cycle length). Nevertheless, this photoperiodism limits the diffusion of the variety to the latitudes close from its original one. Each variety having its own requirements. Finally, agronomical performances of photosensitive varieties are difficult to improve, this could explain that highly photosensitive cultivars are often associated to low yields.

Analysis of the results from 2006 trials
A first trial, performed in Sotuba (Mali), in 2006, analyzed, for six fonio varieties, biomass allocation between roots, stem-leaves (straw) and reproductive organs, in link to six sowing date.

The figure below illustrates, with the exception of one variety at one sowing date, the close link existing between root and straw biomass accumulation. Nevertheless root biomass is lower than 10% (6% in average) of straw biomass. This proportion is low in comparison, for example, to *Sorghum sp.* where it reaches 25 %.

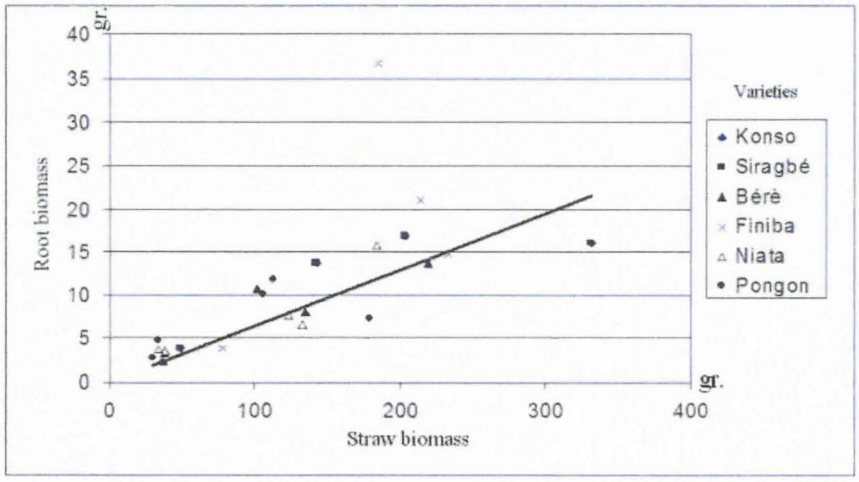


Fig.54. Link between root and straw biomass production in 6 fonio varieties

As the varieties tested were photoperiodic, with a flowering induction under shortening day length, the plants sown later had a shorter vegetative cycle and biomass production than the ones sown earlier (figure below).

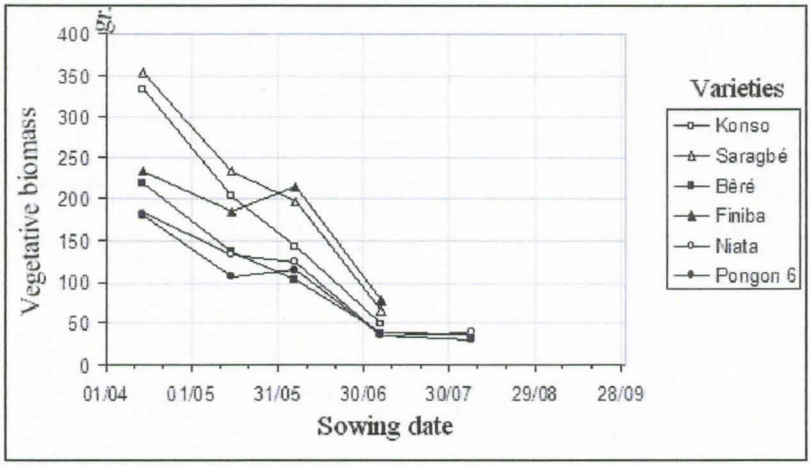


Fig.55. Link between vegetative biomass production and the sowing dates for 6 fonio varieties

Nevertheless, each variety was characterized by its own intrinsic cycle length: among the six varieties compared three are early heading varieties *Finiba, Niata* and *Pongon* while three are late heading varieties *Konso, Saragbé et Bèré* (figure below).

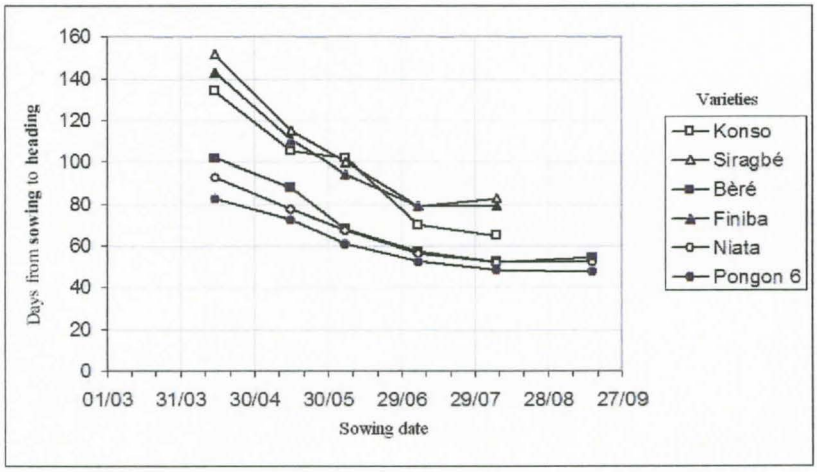
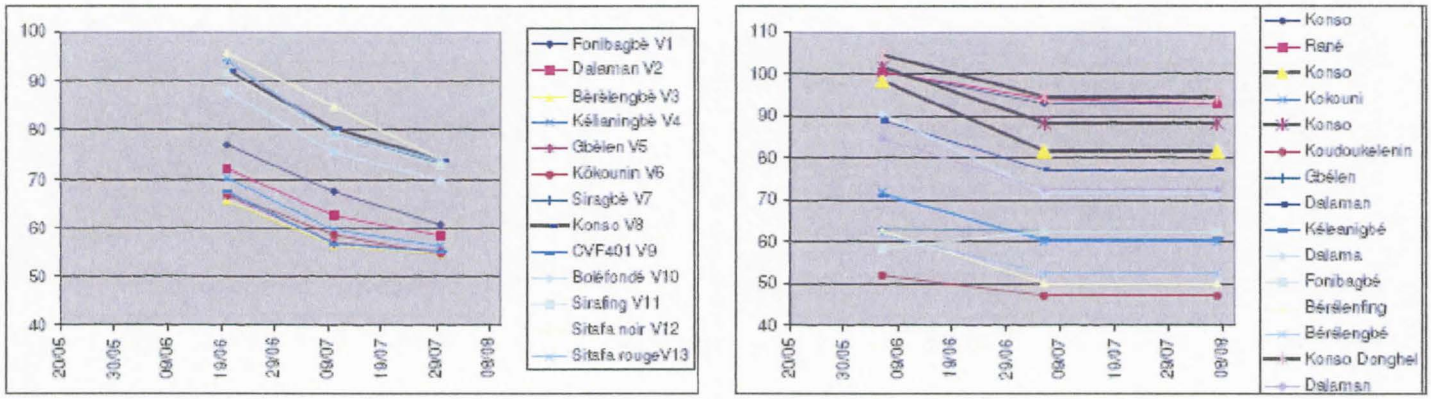


Fig.56. Evolution of 6 varieties cycle length in link to 6 sowing dates

A second trials, including 15 Guinean varieties, tested their response to photoperiod following the application of three sowing dates, this on two sites: Bordo (Guinea) and Sotuba (Mali) (Figures below). The results obtained in Bordo, first plot, underlined two groups of varieties characterized by different intrinsic precocity. The results from Sotuba supported these results even if two varieties, *Gbélen* and *Fonibagbé*, did not response to photoperiod in this last site. This could be link to the lower number of repetitions in Sotuba.



Guinean (left side) and Malian (right side) trials from 2006.

Fig.57. Sowing till flowering fonio cycle length, in days, in function to the sowing date.

The results of these trials were used to calibrate the model developed by Folliard *et al.* (2004) to predict, on the basis of the environmental conditions, the shift from the vegetative to the reproductive stage of photoperiodic species. This model is based on the definition of two parameters the Psat, the photoperiod under wish the length of the vegetative phase remain constant, and the Pbase, the photoperiod upper wish the induction of the reproductive phase is inhibited (figure below). The good performance of the model obtained on the data of *Niata* variety (R^2, reflecting the difference between the predicted and the observed values, ranged from 0.96 and 0.99) has to be validated on independent data that will be recorded on 2007 trials.

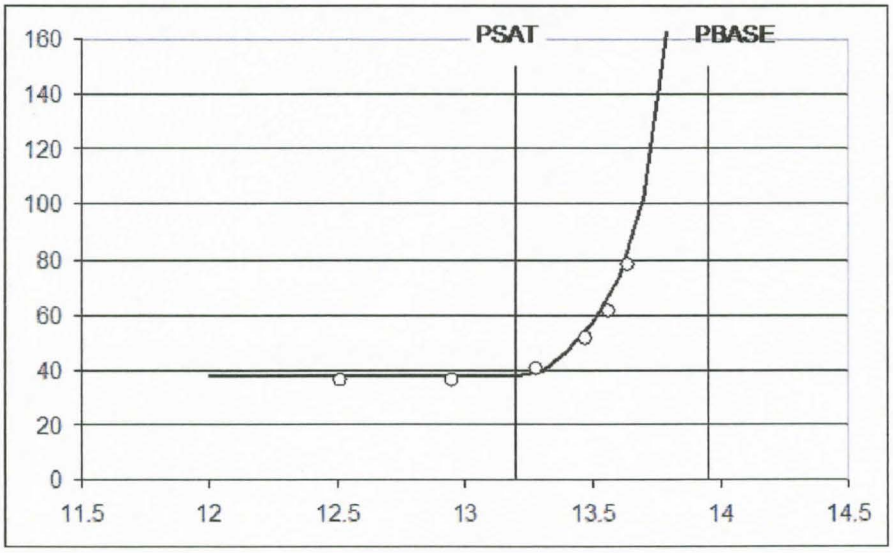


Fig.58. Evolution of the cycle length (days) in function of the photoperiod (hours)

Such model allows predicting variety adaptation and behaviour under different latitudes. Indeed, going north, under higher latitude, maximum day length will increase, increasing, in this way, the cycle length of 'short day length' photoperiodic variety. As an example, the cycle length of *Bèrélenfing* (early heading variety), when sown in April, doubles, shifts from 60 to 120 days, when taking into consideration the cropping sites of Kankan (Guinea – 10.38° Lat N), Sotuba (Mali – 12.65° Lat N) and Mopti (Mali – 14.51° Lat N).

In order to be able to implement agro-climatic model to simulate fonio biomass accumulation, a trial aiming to follow up biomass accumulation and its distribution in its root, stem-leaves and reproductive fractions, was also set up, in 2006, with the variety *Finiba,* in Sotuba.

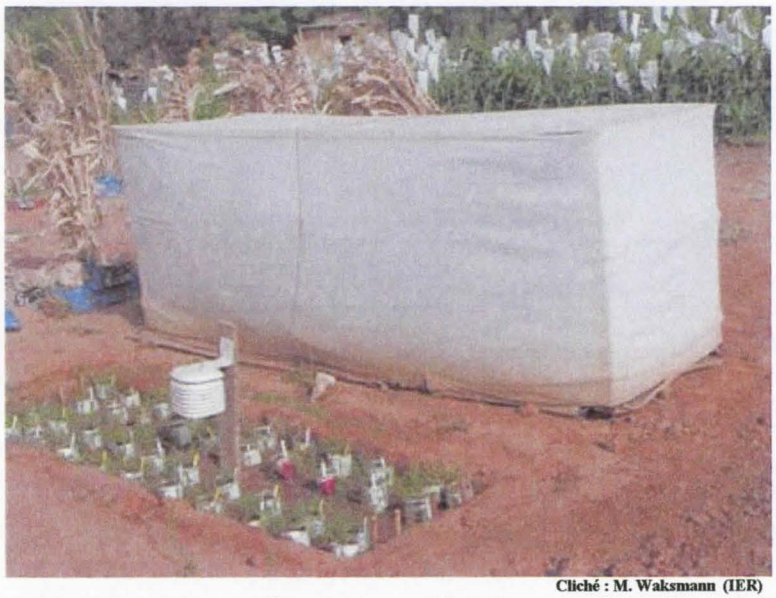
Dates	Green leaves	Death leaves	Stem	Root	Organs for the reproduction
6-juil	33,90%	0,00%	61,02%	5,08%	0,00%
7-août	15,75%	5,20%	67,11%	11,94%	0,00%
12-sept	13,84%	7,79%	69,24%	8,12%	1,00%
18-oct	3,24%	17,05%	64,95%	8,40%	6,36%

The heading date occured the 12 of September.

Table26. Evolution of the biomass allocation during the growing cycle of *Finiba* variety

Green leaves biomass increases till the heading stage before to decrease due to senescence process. Stem; representing 61 to 69 % of fonio biomass; as root biomasses; representing, in average, 9 % of the total biomass; also increase till the heading date.
In order to be able to evaluate the leaf area index of fonio sward, of interest to determine photosynthetic activity potential, the SLA specific leaf area of fonio, linking leaf dry biomass to leaf area, was determined. This specific area evolved, for *Finiba* variety, from 400 cm^2/g, 40 days after the sowing date, to 265 cm^2/g, 110 days after the sowing date. On this basis, leaf area index of fonio population will be determined from leaf biomass harvested on a pre-determined surface.

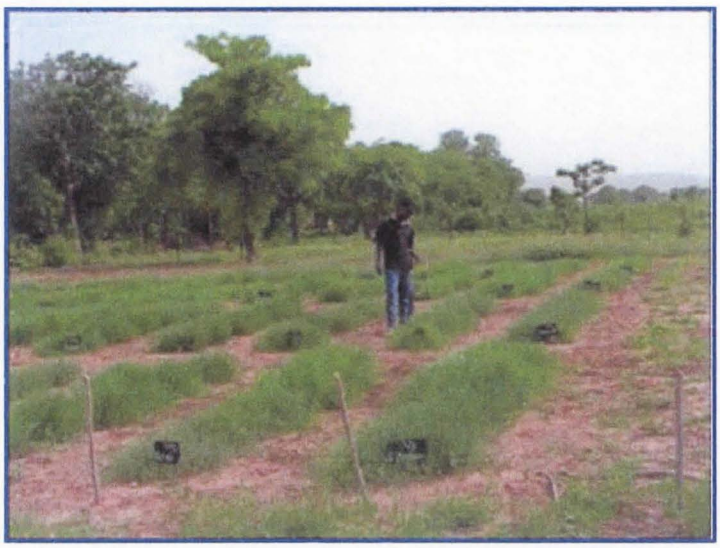
Experiment set up in 2007
In 2007, two experiments were set up to refine the definition of the parameters necessary to characterise fonio response to photoperiod.
In order to analyse intrinsic precocity of the varieties, needing to maintain the day length under the Psat limit, a trial was set-up the 15 of January, in counter season, with the possibility to artificially reduce day length to 9 h in using adapted cover structure (figure below). This was done on the 21varieties from the 1st and 2nd trials from 2006.



Cliché : M. Waksmann (IER)

Fig.59. Experimental cover structure allowing to artificially control day length, in counter season

In order to confirm, implement and adjust the results from the second trial performed in 2006, a similar trial was set-up on two sites, in Bordo (Guinea) and in Sotuba (Mali), in 2007, including the 13 varieties compared in the multi-local varieties comparison trials set up in 2007 (figure below). The 2006 protocol was improved with a greater number of sowing dates, in order to cover period with increasing (04/05 and 17/06) and decreasing (16/07 and 20/09) day length, and a greater number of observations to control the inter-repetition variability. The first analysis of 2007 results confirms 2006 ones.



Cliché : M. Waksmann (IER)

Fig.60. Trial aiming to determine the response of the varieties to the photoperiod in Mali.

2.6.2.2 Responses to water and fertilisers

Responses to water and fertilisers are analyzed on field plots (Bareng, Bordo, Sotuba) and yield indexes (dry matter, grain, fodder..) are discussed in relation with climate and soil water balance parameters and ecotype characteristics (WP1).

Analysis of the results of 2006 trials

To characterize fonio response to fertilizers, two preliminary experimental designs where set up in 2006.

The first trial aims to identify the nutrients of interest (N, P, K, Ca, ...) to be included in a deeper 'fonio nutrient response' investigation. Indeed, the fonio is recognized for its rusticity and can growth on acid and poor soils. So it was expected only modest response to N and P fertilizers with possible response to other nutrients such as Mg and Ca, less available in acid soils.
This trial was set up in the two Guinean experimental sites, Bordo and Bareng, under two conditions, one with and one without basic NPK (22,5 units/ha of each of these nutrients) fertilization.

The modalities tested, twice in each of these two conditions and in each site, were :
* the control, without additional fertilizer,
* the addition of 3T/ha of manure,
* the addition of 50 kg/ha of urea (= 23 kg N/ha),
* the addition of 50 kg/ha of super triple phosphate,
* the addition of 50 kg/ha of KCl,
* the addition of 300 kg/ha of natural Tilemsi phosphate (Mali), its includes also some Ca,
* the addition of dolomie (300 kg/ha), this fertilizer includes Ca and Mg,
* the addition of dolomie (3000 kg/ha) to increase soil pH,
* the addition of 300 kg/ha of $CaSO_4$ (Ca and S),
* the addition of 50 kg/ha of $CaNO_3$ (Ca and N),
* the addition of oligo-nutrients : 6.7 kg/ha of Borax and 6.7 kg/ha of $ZnSO_4$.

Taking into account the 2 repetitions from Bordo and the 2 repetitions from Bareng, the results were analysed as a split plot scheme with the presence or absence of the basic NPK fertilization as the main plots and the different fertilization modalities as the sub-plots.

As the interaction between these two factors was not significant ($p = 0.990$), they were compared independently. So the application of a uniform fertilization of 22.5 units of N, P and K led to significant

yield increase of 29% (p = 0.023). Grain yields were, in average, of 723 and 932 kg/ha, respectively without and with this fertilization level.

Due to the huge variations observed between the different repetitions, there was only a marginally significant effect (p = 0.067) of the different fertilization modalities on fonio grain yield. The modalities "CaNO3" and "Oligo" were significantly different from the "Control" one (figure below). The variation is reflected by the standard error.

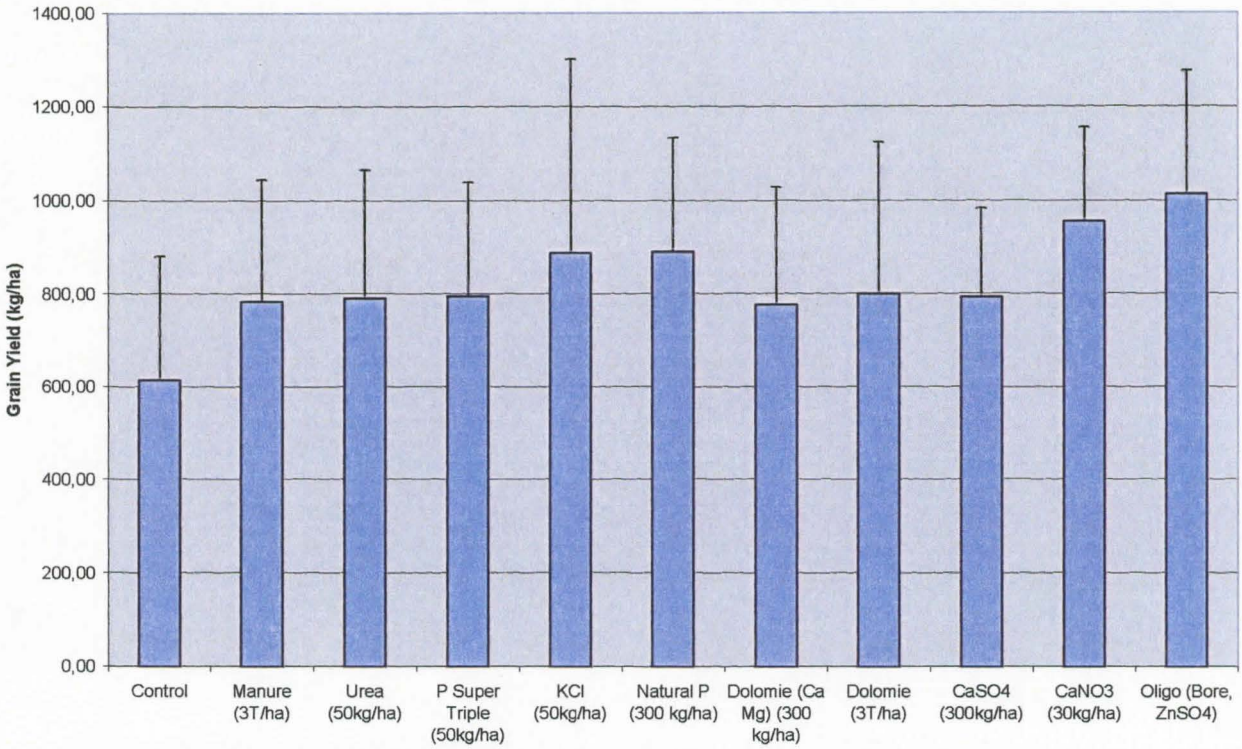


Fig.61. Evaluation of the impact of the different fertilization modalities on fonio yield.

The difficulty to interpret the results of these preliminary trials may be due to the heterogeneity existing within the experimental fields in terms of nutrients distribution. This underlines the necessity to characterize experimental field fertility, in order to determine iso-potential zones, before to initiate a complete fertilization experiment in 2007. This was the aim of the second trial performed in 2006 on the three sites; the two experimental sites from Guinea and the site of Cinzana (Mali), designed to support the complete fertilization experimentations from 2007.

To do so, fonio and millet crops were implanted, respectively on Guinean and Malian fields, and harvested in geo-referenced plots of 50 m². 46 kg of N were applied in order to improve nutrients exportation and to homogenize remaining nutrients content in the soil. The yields were determined in each of these plots and, on this basis, homogeneous field areas had been characterized to implant the different blocs of the 2007 fertilization trials.

Fertilisation trials in 2007

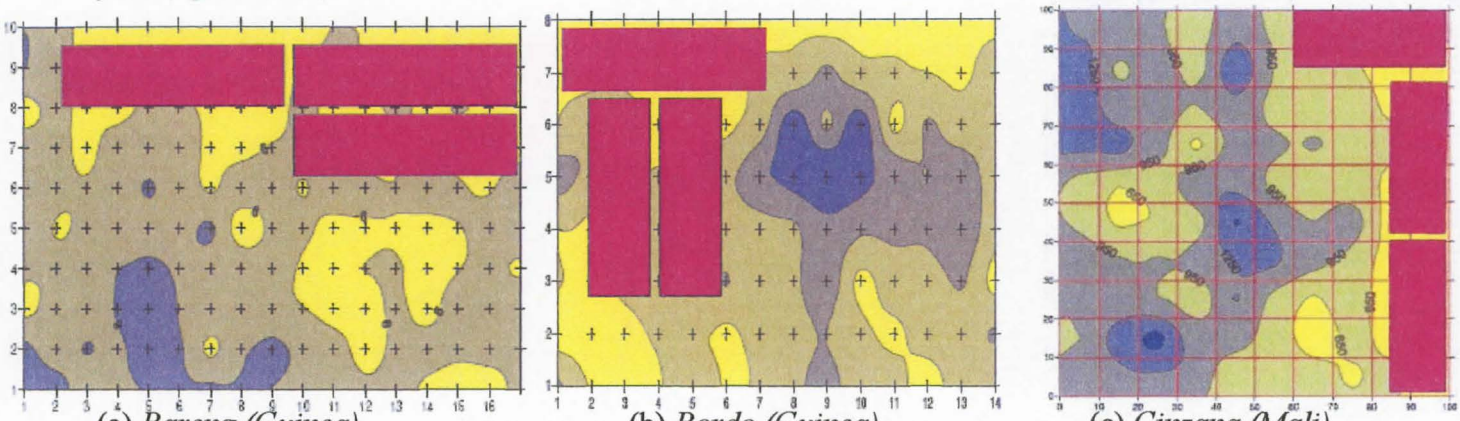
In 2007, fonio response to NPK (3 levels for each nutrient, in a complete factorial design as describe in table below) was analysed in the three fields characterized in 2006.

N	P_2O_5	K_2O
0	0	0
15.0	15.0	15.0
30.0	30.0	30.0

N	P	K
0	0	0
15.0	6.6	12.5
30.0	13.2	24.9

Table27. Levels of NPK fertilizations compared in a complete factorial design (27 modalities)

This in a three blocs design, each bloc was implanted in an area with an iso potential in term of grain yield (figure below).



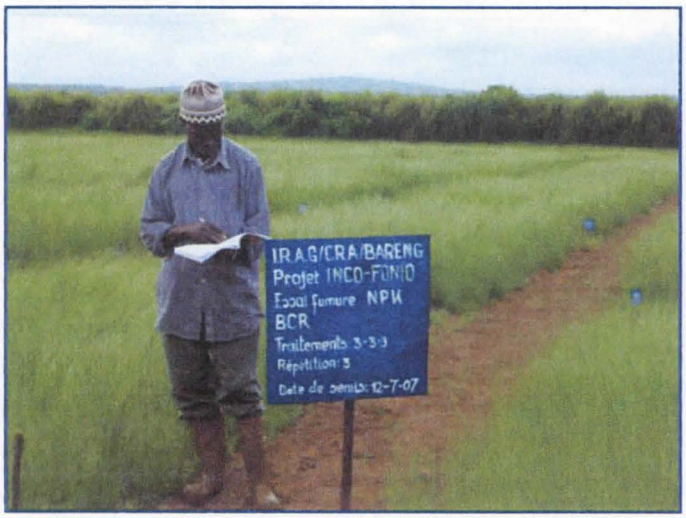
(a) *Bareng (Guinea)* (b) *Bordo (Guinea)* (c) *Cinzana (Mali)*

Fig.62. heterogeneity of the field fertility and localization of the blocs for 2007 trials

The only problem underlined on these three trials is linked to the huge precipitations (close from 100 mm in one day) supported by the trial of Cinzana after fertilizers application.

Such rains had led to water stagnation on the field that was flat and to some possible nutrients diffusion from one plot to the neighbour ones. This could lead to a dilution of the response intensities observed.

However, as some contrasted plots were observed during the after rain tour performed in October, with some low densities associated to the absence of fertilizer application, it was decided to harvest this trial and to decide of its pertinence at the light of the results of the two trials performed in Guinea.



Cliché : T. A. Diallo (IRAG)

Fig.63. Fonio response to NPK in Bareng

Cliché : B. Dupuis (CRAW)

Fig.64. Plot of Cinzana trials attacked by termites

A significant pressure was also exerted by some termites on some plots from Cinzana trial. A quotation of the importance of this pressure on the different plots was also asked during the after rain tour performed in October 2007 in order to be able to take it into consideration, as a covariable, during data analysis.

2.6.3. Diagnosis of local agroecological knowledge on fonio cultivation (task 6.3.)

This task deals with diagnosis of local agroecological knowledge on fonio cultivation and identification of the main factors (varietal, agronomic, socio-economic...) that slow development of fonio production.

2.6.3.1. Implementation of rapid appraisal surveys through open interviews and semi structured questionnaires.

This was performed in collaboration with the WP5

2.6.3.2. Field observations and rapid inventory of systems components and climate environment.

This took part to the task 5.2. in 2007 'Characterise the place of fonio inside the crop-livestock systems and the recent evolutions'. This task analyses the crop rotations and technical itineraries associated to fonio across a subset of 60 farms (20 per country, in link to the typology performed by WP5: 2 villages per country). Early and late varieties were followed up with yield and climatic parameters recording, grain and straw quality characterisation. For most information see paragraph 2.5.2.

2.6.3.3. Gap (potential to reality) analysis (with WP5).

This action will be performed in 2008, through the implementation of most promising varieties identified in some villages to stimulate producer interactions on possible fonio variety innovation.

2.6.4. Closing the gap through innovation and sharing knowledge (task 6.4.)

2.6.4.1. Annual participatory assessment of results implemented with all stakeholders

During the WP5&6 "post rainy season" meeting, in October 2007, exchanges with farmers were organized in villages followed up by the WP5 in Burkina Faso.

Cliché: J. F. Cruz (Cirad)

Fig.65. Exchanges between FONIO project staff and farmers in a village near Orodara (Burkina Faso).

The analysis of these exchanges, reported in a deeper way, but in French, in the 4th seasonal report (Deliverable 36), highlighted the following points.

Whatever the village, the main problems from fonio production remain the threshing and the dehulling post-harvest operations. Some alternatives exist in terms of mechanization (e.g. "fonio thresher" and "GMBF fonio dehuller" perfected and finalized by the previous CFC fonio project) however they need investments and, often, the organization of producers grouping to be available.

Cliché: J. F. Cruz (Cirad)

Fig.66. Traditional threshing with sticks (Burkina)

Cliché: D. Stilmant (CRAW)

GMBF fonio dehuller

For the cropping system, no clear demand exists but some problems can be underlined.

So, in terms of soil preparation and of sowing technique, the technique used give heterogeneous results due to the small seed size. Some improvement with soil packing could be proposed after to have taken into consideration the maintenance of soil structure.

The fertilisation and weed control have to be elaborated in the context of the crops rotation scheme. Indeed, it had been underlined the difficulty to control weed invasion in a fonio crop set up after fallow. Control that is possible when this crop comes after a leguminous species profiting from the back effects of the rotation head (sorghum, millet,...) if they received manure. Such rotation scheme seems to maintain enough fertility for the fonio in order to reduce the pressure exerted by the *Striga hermontica* (figure below) occurring mainly on poor soils. This has to be taken into account during the evaluation of the interest of applying a light fertilization on this crop.

Cliché : E. Vall (Cirdes)

Fig.67. *Striga hermontica* remains a weed difficult to control in fonio crop, especially on poor soil

Due to these different bottlenecks, no clear demand is expressed in term of variety innovation.

2.6.4.2. Scientific discussion, validation of results and issues for the future (zero tillage, mulch based cropping systems..): for 2008.

2.6.4.3. Designing of adoptable site specific measures for enhancing fonio performances : for 2008.

Deviations from the project work program, and corrective actions

There is no deep modification of the work program but a reorganization of the tasks between the WP5 and 6 mainly in the context of the task 6.3. "Diagnosis of local agroecological knowledge on fonio cultivation and identification of the main factors that refrain development of fonio production" managed by the WP5 and to which the WP6 contributes in validating the enquiries and the follow up protocols, for the two first subtasks: "Implementation of surveys" and "Field observations and rapid inventory of systems components and climate environment". In 2008 the WP6 will focus, always in collaboration with WP5, on the point. The third subtask "Gap (potential to reality) analysis" will go on through the implementation of most promising varieties identified in some villages to stimulate producers interactions on possible fonio variety innovation.

List of deliverables, including due date and actual/foreseen submission date

Del. no.	Deliverable name	WP N°	Due date	Actual/ Forecast delivery date	Estimated indicative person-months	Dissemination level	Lead contractor
31	Definitive choice of preliminary study sites in each country	6	3	14	1	RE	CRAW
32	Blue print providing a comparative state of art on existing knowledge on varieties and fonio based cropping systems	6	12	27	4	PU	CRAW
33	Concerted approach and methodological steps for combining biophysical and socio-economic multiscale data	6	3	14	4	RE	CRAW
34	List and conceiving of desirable on field experiments dealing with the characterization of varieties and improvement of biophysical environmental performances of the cropping system	6	3	14	4	RE	CRAW
35	List and conceiving of the farmer's reference associated network. (PRAs…)	6	3	26	4	RE	CRAW
36	Implementation (2 years) of agronomical experiments, 4 seasonal reports	6	33	33	16	RE	CRAW
37	Analysis of results, synthesis and scientific articles production	6	30	33	5	PU	CRAW
38	Varietal catalogue of the most popular fonio varieties	6	12	30	6	PU	CRAW
39	Guidelines for the empowerment of local communities in participative actions for diffusion of innovations	6	30	30	3	PU	CRAW
40	Communication, edition of main results in national regional international meetings	6	35	35	3	PU	CRAW

Justification of putting off deliverable deliverance

Deliverable 32. The delay has to be linked to the desire to include last published data, in 2007, on fonio varieties and genetic diversity within this review. This deliverable has been sent to partners in December 2007 for corrections and comments. The return is expected for February 2008 and final version for March 2008.

Deliverable 35. The final selection of the farmers was only ended in Month 18 as, during the first year, WP5 has focussed on farming systems characterisation.
A version of this deliverable has been sent to the WP5 partners in November 2007 asking them to fill in the farmers references tables. The return is expected for January 2008 and the final version for February 2008.

Deliverable 38. The 42 cultivars collected in 2006 have been planted in Bareng (Guinea) for morphological observations in 2007. The data are now available together with the technological characterisation (WP1). Morphological and qualitative analysed will be integrated in the deliverable that will be published in June 2008.

List of milestones, including due date and actual/foreseen achievement date

Milestone N°	Milestone name	WP n°	Date due	Actual/Forecast delivery date	Lead contractor
M 6.1	Start up workshop to define the organisation of the work within the teams and methodology for task 6.1and 6.2.	6	1	Done in March 06	CRAW & Cirad
M 6.2.	Intermediate meeting to prepare the methodology of tasks 6.3 and 6.4.	6	3	Done in March 06	CRAW
M 6.3.	Decision taking for coordinated experimentation during the first rainy season.	6	4	Done in May 06	CRAW
M 6.4.	Production of site specific diagnosis reports.	6	10	Done in January 07	CRAW & Cirad
M 6.5.	Post rainy season workshop for adjusting activity.	6-5	13	Done in November 06	CRAW & Cirad
M 6.6.	Decision taking for coordinated experimentation during the second rainy season, month16	6	16	Done in April 07	CRAW
M 6.7.	Production of site specific experiments reports, month 22	6	22	Done in October 07	CRAW
M 6.8.	Post rainy season workshop for preparing synthesis, month 25	6-5	25	Done in October 07	CRAW & CIRDES
M 6.9.	Result analysis and final report per activity, month 30.	6	30	30	CRAW
M 6.10.	Final workshop among stakeholders to discuss the results and to identify the global added value,	6	35	35	Cirad & CRAW

There is a close agreement between due and delivery dates.

Section 3 – Consortium management

Consortium management tasks and their achievement; problems which have occurred and how they were solved

The FONIO project, which duration is 3 years, is led by Cirad (participant n°1). Cirad is responsible for the overall management/co-ordination of the project through WP7 undertaking three main activities:

Setting-up of the project management structure, implementation and follow-up

Cirad play the role of interface between Partners and European Commission and manage the overall legal, contractual, financial and administrative aspects according to the contract rules and consortium agreements terms.

At the beginning of the project, the co-ordinator organised the project kick-off meeting that was held in Bamako, Mali, from 20 to 24 March 2006. A steering Committee was set up to help the general coordinator for the overall management of the project through annual meetings. This Steering Committee (SC) is composed of WP leaders plus national co-ordinators when an institution is not WP leader but only deputy.

During the first half of the year, a Consortium Agreement was drawn up in accordance with EU requirements, discussed and signed between all partners to specify all their responsibilities and duties concerning this project.

The coordinator is supported by two services of Cirad (named "Service d'Appui à la Gestion" and "Service Valorisation"). The support services deal with the receipt, allocation and transmission of the Commission's financial contribution to the project partners. They are the permanent contact point for the Commission concerning payments, cost statements and general questions regarding accounting, financial and legal matters for the project.

Implement an effective project communication and reporting

During this year, the web site (http://inco-fonio.cirad.fr/) was updated to assist management (communication flow within the consortium) and disseminate information outside the consortium.
Several web pages have also been produced on Cirad or others partners or European Union sites.

Communication and reporting were also implemented through different meetings and workshops organized during 2006 and 2007.

Project monitoring and evaluation

The different tasks, workpackages, protocols, ... were discussed during the kick off meeting at the beginning of the project and during the specific workshops held during the year;

Information from WP leaders or participants regarding progress of the activities has been reported commonly to the project co-ordinator. These progress notes (usually send by email) contain a review of: the works carried out and the results obtained or of the technical and financial problems temporarily encountered. An evaluation of the project progress was done during the annual meetings held in Montpellier - France (December 2006) and in Libramont – Belgium (November 2007).

During the second reporting period, the consortium management does not face major problems on scientific or technical level as well because all participants involve efficiently in the project. The main difficulty has concerned the administrative level and more precisely the delivery of the "first management report". Because of important social and political troubles (general strike, martial law,...) in Guinea at the very beginning of year (January, February 2007), our Guinean partner (IRAG) met problems to produce on time his financial report. When the local situation became better, the FONIO project coordinator went to Guinea in April 2007 to help IRAG in finalizing the documents. At last, even when the "first activity report was delivered on time the 7 February 2007, the "first management report" was sent to European Commission in May 2007 (with about a quarter delay).

Contractors: Comments regarding contributions, changes in responsibilities and changes to consortium itself , if any

Between June and December 2006, a Consortium Agreement was drawn up, in accordance with EU requirements, and discussed and signed by all partners. This Consortium agreement contains 22 articles and aims to specify all the responsibilities and duties of each contractor concerning this project. The Consortium Agreement reminds the organisation of the FONIO project and gives information about costs, budget and payments, intellectual property rights and liabilities of the Contractors. Its annex gives also data concerning allocation of resources to partners, payment tables and contact persons for administrative and financial matters.

In order to facilitate the relationship between the different partners, each organisation elected a team leader. The role of the team leaders is:

- To organise the work of the different participants of the FONIO project in the country.
- To carry out the syntheses of the activities led by country and to ensure that scientific and financial reports are finalised at the appropriate time.
- To prepare and animate the co-ordination meetings and the technical workshops in the country meet in close cooperation with the coordinator.
- To ensures the necessary relationships to integrate the FONIO Project at a national level.

The team leaders are listed in the table below:

Country	Contractor organisation	Team leader
France	Cirad	Jean-François CRUZ
The Netherlands	Wageningen University	Ms Inge BROUWER
Belgium	CRAW	Didier STILMANT
Mali	IER	Dore GUINDO
Guinea	IRAG	Thierno Alimou DIALLO
Burkina Faso	CIRDES	Eric VALL
Senegal	ENDA Graf	Babacar TOURE

Table28. Organisation team leaders

Every representative of the national institution has the empowerment from his company to commit staff and other resources required by the project.

For the Research activities and as defined in the FONIO project document, the different participants are leaders or deputy leaders of the workpackages as described in the following table

Participants	WP1	WP2	WP3	WP4	WP5	WP6
1 – Cirad (France)	Co Ms G. FLIEDEL		Co Ms S. DURY	Vco Ms S. DURY		VCo F. FOREST
2 – WU (The Netherlands		Co Ms. I. BROUWER				
3 - CRA-W (Belgium)						Co D. STILMANT
4 – IER (Mali)	Vco D. DRAME					
5 – IRAG (Guinea)					Vco T.A. DIALLO	
6 – CIRDES (Burkina)		Vco E. VALL (*)			Co E. VALL	
7 - ENDA-Graf (Senegal)			Vco B. TOURE	Co B. TOURE		

Co: WP Leader, Vco: WP deputy leader (*) for nutritional value of fonio straws

Table29. Contractor involvement in different workpackages (name of leaders)

The Workpackage leaders have the scientific and technique responsibility of the all tasks of their WP. Workpackage leaders are helped by a deputy leader who is fully conversant with the WP and deputise in the absence of the leader.

During the second year, there were not significant changes in the organization envisaged during the elaboration of the FONIO project and which came into force during the project kick off meeting. This organization seems to suit all the partners and was confirmed during the annual meetings which were held in France (year 1) and in Belgium (year 2). What is more, a closely collaboration was established in between "Wageningen University" and "Université National du Bénin" (UNB) for the WP2 tasks implementation. So, a representative of UNB was invited to participate to the second annual meeting in Belgium in order to enlarge the influence zone of the FONIO project in West Africa.

Project timetable and status, including an updated, frontlined barchart

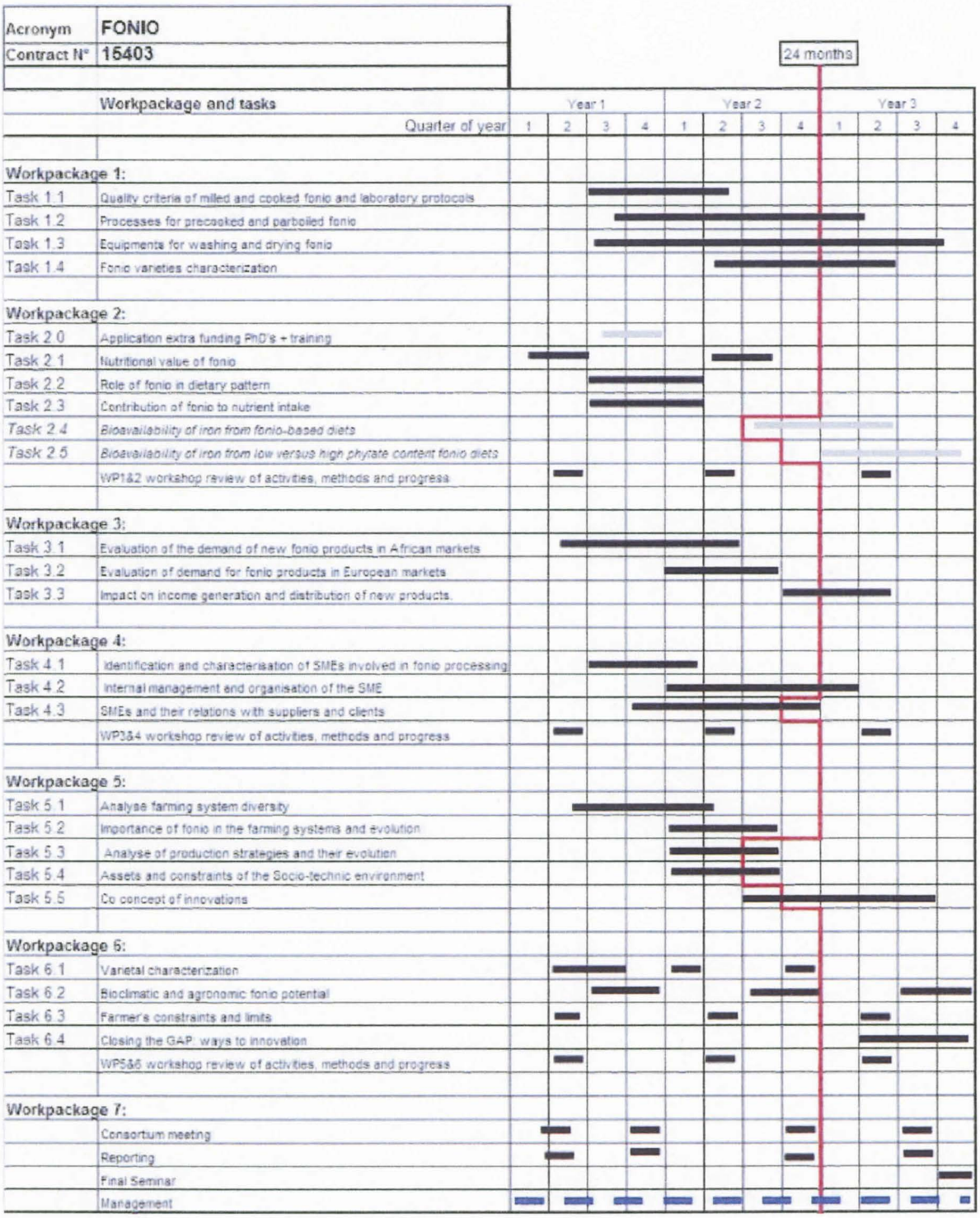


Table28. FONIO project timetable

For some tasks, there are some changes in the timetable corresponding to a delay of 3 months or 6 months mainly due to question about the "Go -No Go decision" of the activity maintenance (tasks 2.4 & 2.5) or for reason of work charge. One must also remind that the real start of the project took place in March 2006, although the official date was 1 January 2006.

Co-ordination activities in the period, communication between partners, project meetings, possible co-operation with other projects/programmes etc.

The general coordinator of the FONIO project was assigned to Cirad in Bamako (Mali) from February 2006 to September 2007. This central geographical position allowed a better communication with West African partners. During the first half of the year 2007, while the general coordinator had a permanent contact with IER (Mali), he visited Burkina Faso in March 2007 and Guinea (IRAG) and Senegal (ENDA) in April 2007. Then, during the second half of the year, he travelled to Mali and Burkina Faso to participate to the WP5&6 meeting, to Mali to organize the WP1 to WP4 meeting and to Belgium to coordinate the second annual meeting. During these visits, the working programme of each institution was discussed and activity results were presented. Administrative and financial aspects of the coordination activities were also taken into consideration.

Reporting
During year 2007, the first 2 months were devoted to reports writing (first activity and first management reports) with collaboration of WPs and team leaders and report of the first annual meeting in Cirad Montpellier (France):

Cruz J.F. 2007. Upgrading quality and competitiveness of fonio for improved livelihoods in West Africa. FONIO project n° 15403. First activity report. Cirad. February 2007. 58p. + appendix.

Cruz J.F. 2007. Upgrading quality and competitiveness of fonio for improved livelihoods in West Africa. FONIO project n° 15403. First management report. Cirad. May 2007. 14p.

Cruz J.F. 2007. Amélioration de la qualité et de la compétitivité de la filière fonio en Afrique de l'Ouest. Projet FONIO n° 15403. Délivrable 41. Rapport de la Réunion annuelle de Montpellier. Cirad. 51p. + annexes

Specific missions
Two specific missions were realised: in Mali and Burkina Faso (March 6-13/2007) to study fonio precooking and in Guinea (April 16-27/2007) to analyse the Guinean fonio commodity chain in collaboration with WP3 and WP4.

Specific meetings
Different meetings were organized during the year 2007

- "WP6 meeting" in Mali (April 2007)
This "pre rainy season" WP6 workshop took place at IER Bamako in Mali (2 - 4 April 2007). This meeting was attended by about ten agricultural scientists coming from Belgium (CRAW), Burkina Faso (Cirdes), Guinea (IRAG) and Mali (IER and Cirad). This workshop was very helpful to exchange and distribute varieties to test in 2007 (Guinea, Mali and Burkina) and to update the various test protocols for the following agricultural campaign.

- "WP3&4 workshop" in Mali (May- June 2007)
The jointed workshop WP3 "The demand for new products and its effects on income generation and distribution" and WP4 "Small scale enterprises and innovation in product and process" took place in Mali (29 May – 2 June 2007). This meeting was attended by a dozen people (scientists and fonio stakeholders) coming from Mali, Guinea, Senegal and France. During this meeting about twenty SMEs of the fonio commodity channel were visited by the FONIO project staff in the towns of Bamako and Ségou.

- "WP5&6 workshop" in Mali and Burkina Faso (October 16- 26/2007)
A "post rainy season" workshop of WP5 (farming systems) and WP6 (cropping systems) was held in Mali (IER Centres of Sotuba, Cinzana and N'Tarla) and in Burkina Faso (Cirdes Centre of BoboDioulasso) from 16 to 26 October 2007. It was attended by some fifteen people (agronomists, specialists in cropping and farming systems…) from Belgium (CRAW), France (Cirad), Burkina Faso

(Cirdes), Guinea (IRAG) and Mali (IER and Cirad). This workshop gave the opportunity to submit and discuss the results obtained by the WP 5 & 6 during the year 2007. It was also possible to discuss with farmers while visiting different villages in the Orodara and Nouna regions.

- "WP1 to 4 workshop" in Mali (Oct./Nov. 2007)
The second WP1 to WP4 workshop, organized jointly by Cirad and IER, took place in Bamako (Mali) from 29 October to 3 November 2007. This meeting was attended by about a dozen people from France (Cirad), Mali (IER), Guinea (IRAG), Benin (Université Abomey Calavi) and Senegal (ENDA Graf). This workshop was helpful to take stock of the tasks implemented by the WP1 to 4 scientists coming from various backgrounds: food technology, nutrition, process engineering, mechanization, social sciences and to plan the remaining activities of each Wp.

- "WP1& WP2 meeting" in The Netherlands (November 2007)
A WP1 & WP2 meeting, hosted by Dr. Inge Brouwer (WP2), took place 22-23 November in Wageningen University (The Netherlands). This meeting was attended by seven persons from The Netherlands (WUR), France (Cirad), Mali (IER) and Benin (Université Abomey Calavi). The objective was mainly to review activities and results of 2007, to plan activities programme for 2008 and to discuss dissemination and publication of results.

Annual meeting

The second annual coordination meeting took place at CRAW Center (Walloon Center of Agricultural Research) in Libramont (Belgium) on 25-29 November 2007. This meeting was attended by the project Steering Committee with representatives of each partner: i.e. the project coordinator, the workpackage leaders and the team leaders coming from France (Cirad), Belgium (CRAW), Holland (University of Wageningen), Mali (IER), Guinea (IRAG), Burkina Faso (Cirdes), Senegal (ENDA Graf). A representative of "Université National du Bénin" (UNB) coming from Benin was invited to participate, as observer, to this second annual meeting in order to enlarge the influence zone of the FONIO project in west Africa. The 4 days meeting was dedicated to present and analyse the research results obtained during the second year, to plan the submission of reports and deliverables and to prepare the activities for the last year of the project. The report of the second annual meeting is available in French:

Cruz J.F. 2007. Amélioration de la qualité et de la compétitivité de la filière fonio en Afrique de l'Ouest. Projet FONIO n° 15403. Délivrable 41b. Rapport de la Réunion annuelle de Libramont. Décembre 2007. Montpellier. Cirad. 54p. + annexes

Cliché CRAW

Fig.68. FONIO project staff during annual meeting in Libramont (Belgium)

Next meetings or workshops

As the FONIO project aim is to promote work "in the field" and to strengthen the relationships with the private sector, an important part of the European scientists work consists in research and support missions in the DCs. Project management partially operates on the basis of the planning of coordination meetings and scientific workshops. The table below here gives the updated provisional meeting calendar elaborated during the second annual meeting in Libramont.

Meetings	Country	Participants	Month	Duration (days)
Start-up coordination meeting	*Mali*	*Steering Committee + local staff involved*	*3*	*4*
WP5 and WP6 workshop	*Mali*	*Researchers involved*	*3*	*2*
WP1,WP2,WP3 & WP4 workshop	*Senegal*	*Researchers involved*	*6*	*5*
WP5 and WP6 workshop	*Guinea & Mali*	*Researchers + staff involved*	*3*	*15*
Annual coordination meeting	*France*	*Steering Committee + local staff involved*	*12*	*4*
WP6 "pre rainy season" meeting	*Mali*	*Researchers involved*	*16*	*2*
WP3 –WP4 workshop	*Mali*	*Researchers involved*	*18*	*5*
WP5 and WP6 workshop	*Mali-Burkina*	*Researchers involved*	*22*	*8*
WP1,WP2, WP3, WP4workshop	*Mali*	*Researchers involved*	*22*	*5*
WP1 and WP2 workshop	*Netherlands*	*Researchers involved*	*25*	*2*
Annual coordination meeting	*Belgium*	*Steering Committee + local staff involved*	*23*	*4*
WP1 to WP4 workshop	Mali	Researchers involved	27	5
WP5 & WP6 workshop	Mali	Researchers involved	27	5
Final annual meeting	Senegal	Steering Committee	33	4
Final seminar	Mali	Steering Committee + researchers involved + NGOs	35	4

Table29. Updated FONIO meetings timetable

Comments
After the annual meeting, coordination finally proposed to organize a FONIO seminar in margin of an international agricultural show such as the SIAGRI (International Show of Agriculture of Bamako in Mali) in order to widen the potential audience, to diversify the public which can take part in such a seminar and to increase by it the impact by a media cover possibly more significant.
The SIAGRI 2008 of Bamako is programmed for April 2008 and this opportunity can be taken to organize a "Fonio day". The team leader of the project in Mali (D. Guindo) and the coordinator (J.F. Cruz) will contact the staff of APCAM (Assemblée Permanente des Chambres d'Agriculture du Mali), organizer of the Show, to get the agreement and to plan the presentations.

Collaboration with other projects/programmes

During this reporting period, some researchers, because of to their expertise acquired in knowledge of fonio have maintained relations with other projects or institutions located in West Africa.

- Collaboration with an NGO in Mali which aim to improve the fonio commodity chain in the zone of Kenieba (near the border with Guinea). In this zone, some producers recently met in association in order to improve the production, the processing and the marketing of fonio through the fair trade label named "Ethiquable". One of the activities of the Ngo is to improve the post harvest technologies (processing, drying,..)

- Collaboration with a Spanish NGO (Intervida) located in Mali which had purchased GMBF dehullers for rural populations near the Niger River (Ségou Region). They want to develop the culture of fonio on lateritic ruined agronomic zones to gather food stocks for local populations and commercialize surpluses.

- Collaboration with the Dynafiv ("dynamisation des filières vivrières") project in Guinea. This project develops macroeconomic approach to driven commodity chains (i.e. fonio) and gives assistance promoting discussions, training and information to stakeholders. During a mission in Guinea in April 2007, the coordinator and scientists from WP3, WP4 and WP6 got the opportunity to take part in a documentary on fonio processing and to participate in a radio programme about fonio channel in Guinea. They discussed as well with the Dynafiv project staff, the way to collaborate on the fonio channel.

Web site

The web site of the FONIO project created by Cirad in April 2006 is regularly updated. The Web site is available in French and in English and its URL is http://inco-fonio.cirad.fr/. (or http://inco-fonio-en.cirad.fr/ for the English version). The web site has a reserved section for the only contractors of the project (members only) on which are diffused all internal or confidential information.

Fig.69. Inco-Fonio web site

The statistics illustrated by the histogram below show the numbers of visits per month and the trends along the year. The web site receive between 600 and 800 visits (817 in June 2007). The web site is updated as frequently as possible with the information provided by each contractor

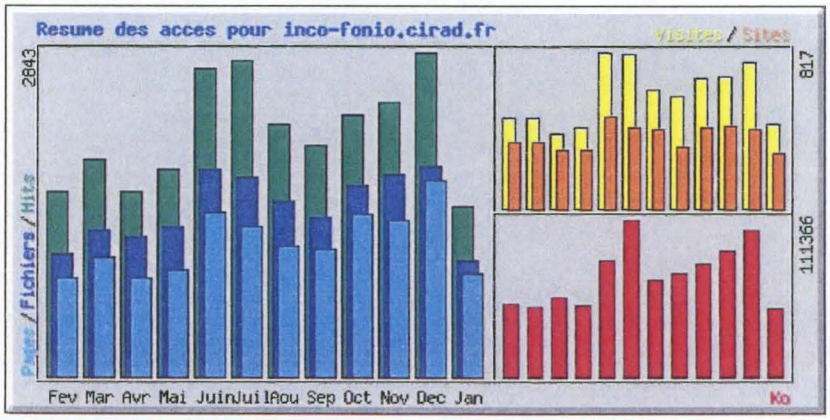


Fig.70. Histogram of numbers of visits (hits, ...) per month in 2007 (Inco-Fonio web site)

List of deliverables, including due date and actual/foreseen submission date

Del N°.	Deliverable name	WP N°.	Date due	Actual/ Forecast delivery date	Estimated indicative person-months *)	Used indicative person-months *)	Lead contractor
41	Annual and Final reports	7	13, 25, 37	14,17,26,37	12	8	Cirad
42	Web site	7	6	4	2	2	Cirad
43	CD Rom (compilation of the main scientific and technological results)	1	37	37	3		Cirad

Justification of putting off deliverable deliverance:

There is a close agreement between due and delivery dates.

The main difficulty has concerned the delivery of the "first management report". Because of important social and political troubles in Guinea at the very beginning of year (January, February 2007), the Guinean partner (IRAG) met problems to produce on time his financial report. At last, even when the "first activity report was delivered on time (month 14), the "first management report" was sent to European Commission in May 2007 (month 17).

List of milestones, including due date and actual/foreseen achievement date

Milestone no.	Milestone name	WP n°.	Date due	Actual/Forecast delivery date	Lead contractor
M7.1.	Inaugural meeting to initiate the action and define in details the strategy.	7	1	Done in March 2006	Cirad
M7.2.	Annual co-ordination meetings Month 12 and month 23.	7	12, 24	Done in Dec 2006 Done in Nov 2007	Cirad
M7.3.	Participation to scientific and technical workshops Month 3, 6, 13, 18, 25, 26.	7	3, 6, 13,18, 25,26	Done in March &June 06 Done in November 06 Done in April 2007 Done in June 2007 Done in October 2007 Done in November 2007 Scheduled 25,26	Cirad
M7.4.	Final annual meeting	7	33	Scheduled 33	Cirad
M7.5.	Fonio day during agricultural show in Mali	7	35	Scheduled 28	Cirad

Appendix 1 – Plan for using and disseminating the knowledge

Section 1 – Exploitable knowledge and its Use

At this stage of the project, exploitable knowledge in terms of equipments concerns mainly the driers i.e. the greenhouse solar drier called "CSec-Serre" and the counter current cross-flow dryer called "CSec-T" dryer. The first one was built and tested at the UCODAL processing unit in Bamako and the second one is now at the Danaya enterprise in Bamako. The experiments carried out with these equipments were very satisfactory in term of drying time, final moisture content and product quantity dried per day (300-400 kg/day). So, in Mali, the NGO "Le Damier" that produce fair trade fonio for export (trade mark "ethiquable") plan to buy soon a greenhouse dryer.

Concerning fonio farming systems, exploitable knowledge is:
- Knowledge on the structural characteristics of the producing exploitations of fonio according to agro-climatic zones
- Knowledge on the farming practices of the fonio according to agro-climatic zones
- Knowledge on the factors of variation of the output of the fonio according to agro-climatic zones

This knowledge is used to identify the constraints and the possibilities of innovations to improve the productivity and the place of the fonio in the producing exploitations of fonio

Section 2 – Dissemination of knowledge

The implementation and the first results of the research activities have been presented to different stakeholders during the specific workshops organized during the year 2007. So, during the WP3&4 workshop on May in Mali, some processors from Bamako were invited to participate to the meeting. During the "post rainy season" workshop on October in Mali and Burkina Faso, project' staff met producers leaders in some villages to present FONIO project. On April, during a mission in Guinea, the Project coordinator and scientists from WP3, WP4 and WP6 got also the opportunity to take part in a documentary on fonio processing and to participate in a radio programme about fonio channel in Guinea. This radio programme will be diffused to a large audience by local rural radio stations in the country.

For other stakeholders (targeting professionals, scientists, policy makers, decisions makers,...), project leaflets were distributed during meetings (e.g. with Agriculture Minister in Guinea, with The French ambassador in Mali, ..) or during Agricultural or Scientific Shows (SIAGRI and Smara in Mali, ...).

Some papers or posters were also published:

Dury S., Meuriot V., Fliedel G., Blancher, Boré Guindo F., Dramé D., Bricas N., Dialité L. et Cruz J.F., 2007. The retail market prices of fonio reveal the demand for quality characteristics in Bamako, Mali. Communication at 106th seminar of the European Association of Agricultural Economists "Pro-poor development in low income countries: Food, agriculture, trade, and environment", Montpellier, France, 25-27 October, 15 p.

Koreissi Y., Brouwer I., Hulshof P., Zimmermann M., 2007. Nutritional aspects of fonio and fonio products. Poster *in* 7th International food data conference. Food Composition and Biodiversity. Sao Paulo, Brazil, October 21-24, 2007.

For larger public information, the WEB site is developed (http://inco-fonio.cirad.fr) and, since the beginning of the project, several web pages have also been produced on the European FONIO project:

"Cirad" or Agropolis pages
http://www.cirad.fr/en/actualite/communique.php?id=501
http://umr-qualisud.cirad.fr/projet_de_recherche/axe_1_theme_1_1/amelioration_de_la_qualite_de_la_filiere_fonio
www.agropolis-international.net/pdf/lettre/lettre_122.pdf

"CRAW" pages
http://www.cra.wallonie.be/module/newsletter/index.php?ID=76&Action=view
www.cra.wallonie.be/module/craw_info/craw_info_pdf/craw-info-16-2007.pdf

"European Union" pages
http://ec.europa.eu/research/headlines/news/article_06_09_22_en.html
http://cordis.europa.eu/fetch?CALLER=EN_NEWS&ACTION=D&SESSION=&RCN=26409

Other Web pages
http://www.underutilized-species.org/record_details.asp?id=701
http://www.underutilized-species.org/MasksSearch/SearchProjectDetail.aspx?id=227
http://www.seedquest.com/News/releases/2006/august/16742.htm

Overview table

Planned/ actual dates	Type	Type of audience	Countries addressed	Size of audience	Partner involved
April 2006	Project Web site	General public Researchers	All countries	600-800 visits /month	Cirad
September 2007	Web page	General public Researchers	All countries		CRAW
June 2006	Research show (SMARA)	Researchers	Mali	100	Cirad IER
June 2006	Leaflets	Researchers Stakeholders	West Africa Europe		Cirad
November 2006	Agricultural show SIAGRI	General public Researchers	Mali	300	IER
Planned	Agricultural show SIAGRI	General public Researchers	Mali	300	Cirad IER
October 2007	Poster	Researchers General public	All countries		WUR
Planned	Posters	Researchers General public	West africa		All partners
April 2007	Radio programme	General public	Guinea	Several hundred	IRAG Cirad, ENDA
Planned	Publications	Researchers	international		All partners
On going	Database	Researchers	All countries		Cirdes
On going	Technical reports	Researchers Manufacturers	All countries		Cirad & IER
October 2007	Article	Researchers	international		Cirad & IER
Planned	Articles	Researchers General public	international		All partners
April 2007	Demonstration	Stakeholders	Guinea		Cirad, IRAG
Planned	Drawings Demonstration	Manufacturers Processors	Mali		IER/Cirad
Planned	Conference	Researchers Stakeholders	West Africa	50-100	All partners

Table30. Overview table to disseminate knowledge

Web site
The web site is updated periodically with the information provided by each contractor. To increase the web site audience, each partner is encouraged to create a link to fonio web site on his own organisation web site and to participate as frequently as possible to scientific or technical exhibitions in order to present the FONIO project.

Agricultural show
Another activity to disseminate knowledge concerned participation to agricultural shows:
- Participation of Cirad and IER to SMARA (Semaine de la Recherche Agricole du Mali) during one week in Bamako June 2006
- Participation of IER to SIAGRI (Salon International de l'Agriculture) during one week in Bamako (Mali) in November 2006.
Research scientists will attempt to present the FONIO project and the results obtained in the countries where national or regional agricultural shows are organised, (Burkina, Senegal, Mali,..). This also might be an opportunity to inform a large public through television, radio or newspaper interview.

FONIO project will participate to the next agricultural show (SIAGRI) organized in Mali by APCAM in April 2008. It is suggested to have an exhibition stand with produces of fonio (for local or export markets), new machines (e.g. GMBF dehuller) and posters presenting different results. A fonio day will also be organised during this biennial agricultural show

WP5 staff (Cirdes) will participate in the festival of the fonio planned in Bondorokuy (Nouna in January 2007)

Leaflets
Leaflets presenting FONIO project and fonio processing were elaborated and given to some stakeholders, processors who participate to international meetings (i.e. UCODAL firm has participate to the first « fair trade show » in France , Aubagne November 2006) or to visitors or guests: UEMOA parliamentarians visiting Sotuba IER Station in August 2006, French ambassador visiting Cirad-Mali in March 2007.

Posters
Posters presenting activities and results of FONIO project will be presented on national or international meetings.

Koreissi Y, Fanou N, Brouwer ID, Hulshof PJM, Zimmermann MB. 2007. Nutritional aspects of fonio and fonio products. Poster presented at the 7th International Food Data Conference in Sao Paulo, 22-24 October 2007

Database
A regional database on the farming systems integrating the fonio was elaborated by CIRDES

Conference
S. Dury, V. Meuriot, G. Fliedel, S. Blancher, F. Bore Guindo, D. Dramé, N. Bricas, L. Diakité, J-F Cruz. The retail market prices of fonio reveal the demand for quality characteristics in Bamako, Mali. *Contributed Paper prepared for presentation at the 106th seminar of the European Association of Agricultural Economists* Pro-poor development in low income countries: Food, agriculture, trade, and environment 25-27 October 2007 – Montpellier, France.

*Paper accepted with minor corrections. A*vailable, on the internet at AgEcon Search: Research in Agricultural and Applied Economics. It is an electronic library dedicated to collecting, indexing, preserving, and distributing full-text copies of scholarly research in the discipline of Agricultural and Applied Economics. http://agecon.lib.umn.edu .

During the next agricultural show (SIAGRI) in Mali, a conference will be organized (29 April 2008) to present to a large public the results obtained by FONIO research teams within the different workpackages.

Presentation

Brouwer ID. 2007. Biodiversity, dietary diversity and food composition tables. Presentation at the 8th International Graduate Course on Production and Use of Food Composition Data in Nutrition. 1-13 Oct 2007, Wageningen. The Netherlands.

Demonstration

Demonstration of the use of various equipments elaborated within the WP1 (driers, ...) were organised for processors (e.g. Ucodal and Danaya in Mali,...). The transfer of drawing and exploitable result was also discussed with manufacturers interested (e.g. Mod engineering in Bamako).

Technical reports

During all the project period, technical and specific reports are produced after each step passed by the research teams. Some of these technical reports could be used by stakeholders as technical guides.

The technical notes or reports produced during the second reporting period are the following

WP1

- Marouzé C., Dramé D., 2007. Projet FONIO. WP1- Activité 3 : Équipements de séchage de fonio. Compte rendu des travaux du CIRAD avec la collaboration de l'IER. 18 p.
- Marouzé C., 2007. Guide d'utilisation du séchoir à flux traversant CIRAD. 4p.
- Marouzé C., 2007. Guide d'utilisation du séchoir serre CIRAD. 1p.
- Rivier M., Cruz J.F., 2007. Étude de la précuisson du fonio au sein de petites entreprises de transformation à Bamako (Mali) et à Ouagadougou (Burkina Faso). Projet FONIO. Cirad. Montpellier. 22p.
- Pivette C., 2007 Optimisation des conditions d'étuvage du fonio en vue d'améliorer ses qualités technologique. Mémoire Ingénieur de l'INSFA. AgroCampus Rennes, Supagro Montpellier. Cirad Montpellier. 30p + annexes

WP2

- Dam B van. 2007. Identification of factors predicting fonio consumption of urban Malian women in reproductive age. MSc thesis Wageningen University.
- Doets E. 2007. Quality evaluation and update of food composition table of Mali (TACAM 2004). MSc thesis Wageningen University

WP3

- Bricas N., 2007. Rapport de Mission en Guinée (17-29 avril 2007). Projet FONIO. Cirad ES, 10 p.
- Dury S., Cruz J.F., 2007. Rapport de Mission au Mali du 29 Mai au 12 Juin 2007. Projet FONIO. Cirad ES et Cirad Persyst, 16 p.
- Dury S., 2007. les consommateurs de précuits. Dépouillement des données d'enquête 2006 sur les achats et les acheteurs de fonio à Bamako.
- Ndiaye M., 2007. Identification et caractérisation des restaurateurs, commerçants et transformateurs de fonio à Kindia et Conakry en 2006. Rapport de synthèse. Projet FONIO. IRAG. Centre de Foulaya, Kindia. Novembre. 12 p.
- Ndiaye M., 2007. Inventaire et typologie des commerçants distributeurs de Conakry et Kindia. Rapport d'enquête. Projet FONIO. IRAG. Centre de Foulaya, Kindia. Novembre. 13 p.
- Ndiaye M., 2007. Rapport d'enquête sur l'inventaire et la caractérisation des PME fonio en Guinée. Projet FONIO. IRAG. Centre de Foulaya, Kindia. Juin. 14 p.
- Ndiaye M., 2007. Identification et caractérisation des restaurateurs, commerçants et transformateurs de fonio à Kindia et Conakry en 2006. Rapport de synthèse. Projet FONIO. IRAG. Centre de Foulaya, Kindia. Novembre.12 p.
- Diakité L., Traoré M., 2006. Actualisation des connaissances sur la consommation la commercialisation et la transformation du fonio à Bamako Rapport d'activités de l'année 1 du volet socio-économie. IER. Sotuba ECOFIL. Décembre. 50 p + annexes.
- Lebrun M., 2007. Etude qualitative de l'acceptabilité du fonio pour les consommateurs potentiels français non issus de la diaspora africaine. Rapport de stage de deuxième année. CIRAD, SupAgro. Août.
- Lebrun M., 2007. Mesure du poids des différents attributs et labels dans l'appréciation d'un produit nouveau par les consommateurs : le cas du fonio. Rapport de stage CIRAD. Décembre. 46 p.

WP5

- Béavogui F., 2007. Systems of production integrating the fonio in Guinea. Kankan : IRAG Work Document, Inco Fonio project, WP5, 26 p.
- Daho B., 2007. Analysis of the diversity of producers and the place of fonio in the system of production in Burkina Faso. Bobo-Dioulasso : CIRDES, Work document, Inco Fonio project, WP5, 49 p.
- Sogodogo D., 2007. Analysis of the diversity of the producers and place of the fonio in the system of production in Mali. Cinzana : IER, Work Document, Inco Fonio project, WP5, 43p
- Daho B., Vall E., 2007. Characterization of the place of the fonio in the systems of production: ground Burkina Faso. Bobo-Dioulasso : CIRDES, Work Document, Inco Fonio project, WP5, 31 p.

WP6

- Cissé, N.F., 2007. Rapport d'expérimentation relative aux comparaisons variétales menées en 2006 à Bordo (Guinée). Projet FONIO. IRAG. 13 p.
- Dupuis B., 2007. Acquisition des connaissances sur les systèmes de culture à base de fonio et voies d'amélioration de la productivité. Rapport de la réunion de coordination du WP6 à Bamako (3-4 avril 2007). CRAW. 24p + annexes.
- Dupuis B., Gigou J., Vaksmann M., Cissé N'F., Forest F., Stilmant D., 2007. Délivrable34. Liste et conception des expérimentations de terrain appropriées concernant la caractérisation variétale et l'amélioration des performances de l'environnement biophysique du système de culture. Projet FONIO. 21 p.
- Forest F., 2007. Délivrable31. Choix définitif des sites pour les études préliminaires dans chaque pays. Projet FONIO. 25 p.
- Forest F., 2007. Délivrable33- Approche concertée et étapes méthodologiques pour combiner des données biophysiques et socio-économiques à différentes échelles. Projet FONIO. 22 p.
- Gigou, J., 2007. Rapport des essais préliminaires 'réponse aux engrais' menés en 2006. Projet FONIO. IRAG. 18 p.
- Sanogo M.D., Konate A., 2007. Rapport d'expérimentation relative aux comparaisons variétales menées en 2006 à Cinzana (Mali). Projet FONIO. IER Cinzana. 3 p.
- Stilmant D., 2007. Délivrable36(4). Réalisation des expérimentations agronomiques - 4ème rapport saisonnier (Implementation of agronomic experiments - 4th seasonal report). 18p.
- Teketé M.L., 2007. Réaction à la Photopériode de quelques variétés malienne et guinéenne de fonio. Mémoire de fin d'études pour l'obtention du Diplôme d'Ingénieur Agronome de l'Institut Polytechnique Rural de Formation et de Recherche Appliquée de Katibougou (Mali), 54 p.
- Diallo T.A. et al., 2007. Rapport d'expérimentation relative aux comparaisons variétales menées en 2006 à Bareng (Guinée). Projet FONIO. IRAG. 14 p.

Section 3 – Publishable results

S. Dury, V. Meuriot, G. Fliedel, S. Blancher, F. Bore Guindo, D. Dramé, N. Bricas, L. Diakité, J-F Cruz. 2007. The retail market prices of fonio reveal the demand for quality characteristics. Submitted to the European Review of Agricultural Economics. November 2007.

Scientific papers presenting research results obtained within WPs are planned to be proposed for publication in 2008.

WP1
Cereal science or journal of agricultural and food science
Physical and mechanical properties of fonio grain, as well as starch and rheological properties of cooked grain.
Cahiers Agriculture
Technologie post récolte du fonio
AMA (african and asian mechanisation)
Mécanisation/ séchage du fonio

WP1 et WP2
Journal of Food Quality and Analysis (?)

Varietal differences in nutrient value, milling and cooking properties, physico-chemical characteristics and sensory characteristics of fonio.
Effect of intensity of parboiling.

WP2
Journal of Food Quality and Analysis (?)
Effect of processing on mineral level
Journal of Public Health Nutrition
Evaluation of food composition table of Mali
Factors determining intention of fonio consumption of urban Malian women
Journal of Nutrition
Validation of dietary diversity as indicator of nutrient adequacy
Validation of 24 hour recall compared to weighed food record and chemical analysis
Iron bioavailability of fonio based diets and effect of phytase and ascorbic acid

WP3
Cahiers Agriculture
Effets de la mécanisation et des nouveaux produits du fonio sur l'emploi, la création d'entreprise et la consommation.
Journal of African economies
The effects of individual and environmental factors on demand for new food products : the case of fonio in Bamako
Food quality and Preferences
The effects of individual and environmental factors on demand for new food products : the case of fonio in Montpellier
Journal of African economies
Effet des variables individuelles et contextuelles sur la demande en fonio

WP4
Analyse de la construction de la réussite dans les entreprises fonio : logiques sociales et réalités économiques
Entreprenariat féminin, emploi et distribution des revenus dans les entreprises fonio.

WP5
Revue à déterminer
« L'effet fonio » sur la durabilité des systèmes de production (social, environnement, économie)
Cahiers Agriculture
Agronomie pratique du fonio : savoir paysans, pratiques locales…
Multifonctionnalité du fonio dans les systèmes de production (sécurité alimentaire, culture, …)

WP6
Cahiers Agriculture
Photopériodisme du fonio
Journal of Agronomy and Crop Science or *African crop science society.*
Etude des interactions variétés* environnement sous des conditions pédoclimatiques contrastées
JACS
Comparaison du photopériodisme du fonio, du mil et du sorgho
Réponse du fonio à la fertilisation
Adaptation au fonio du modèle agro-metéo développé pour le mil

Other
Base de données sur ressources phytogénétiques. Bioversity (Ex-IPGRI).
Fiches variétales : descripteurs morphologiques et technologiques.

Appendix 2 – Fonio food composition table 2007

Table **Fonio Food Composition Table 2007**
FCS07 code = food cosumption study 2007
Code in source = code in TACAM (2004)
Source in reference= Reference cited in TACAM (2004)

				Macronutrients							Micronutrients						
																Vitamin A	
FFCT07	CODE IN SOURCE	ORIGINAL SOURCE	NAME of foods	Moist	E	E	Prot	Fat	CHO	Dietary Fiber	Ca	Fe	Zn	Vit C	Retinol	RAE	ß carotene
CODE				g	Kj	Kcal	g	g	g	g	mg	mg	mg	mg		ug	ug
Cereals & grains products group																	
1	1281	CTA. ECSA (1988) Aliment 19	Bread wheat white	41.6	865	207	6.7	1.0	45.6	2.0	11	3.0	0.7	0	0	0	1
2	376	Barikmo et al (2002	Fonio husked grains dried*	12.0	1323	316	6.7	1.2	74.3	2.2	26	3.9	1.3	0	0	0	1
3	15	SEF/SNT/UiO (2001) aliment 5.016	Macaroni dried	9.0	1395	333	11.9	1.3	73.1	4.2	25	1.0	1.4	0	0	0	0
4	367	Barikmo et al (2002)	Maize grain crushed yellow raw	11.0	1303	311	7.8	0.7	73.0	4.6	8	4.2	0.4	0	0	9	110
5	4163	USDA. 1975	Maize popcorn yellow	3.1	1724	412	9.8	21.8	47.1	12.0	8	2.1	3.8	0	0	6	66
6	370	Barikmo et al (2002)	Pearl millet flour without bran	12.0	1244	297	8.5	3.2	62.5	6.2	14	9.6	5.3	0	0	0	3
7	372	Barikmo et al (2002)	Rice white polished raw	11.0	1357	324	6.6	0.5	78.2	1.1	8	0.4	1.0	0	0	0	4
8	374	Barikmo et al (2002)	Sorghum flour	11.0	1365	326	10.0	1.7	72.2	4.7	12	11.8	1.0	0	0	0	1
9	375	Barikmo et al (2002)	Wheat flour white	11.8	1326	317	9.3	1.5	71.0	3.0	13	2.1	0.6	0	0	0	2
Starchy foods roots & tubers group																	
10		Yao et al (2006)	Cassava attieké dried	12.0	1392	333	1.3	0.0	87.3	1.7	47	1.8	1.6	0	0	0	0
11	152	CTA (1988) aliment 29	Plantain ripe raw	65.0	534	128	1.2	0.3	32.0	1.2	8	0.6	0.1	20	0	33	390
12	50	CTA. ECSA (1988) aliment 30	Potato raw	78.0	315	75	1.7	0.1	18.0	1.0	13	1.1	0.2	21	0	1	12
13	47	CTA. ECSA (1988) aliment 32	Sweet potato pale raw	68.8	474	113	1.6	0.2	28.0	[1.0]	33	0.8	0.4	37	0	3	35
14	44	CTA. ECSA (1988) aliment 35	Yam tuber fresh	69.0	463	111	1.9	0.2	27.0	1.3	52	0.8	0.3	6	0	1	15
Nuts legumes & products group																	
15	380	Barikmo (2002)/ Nordeide et al (1996)	African locust bean seeds fermented	18.4	1785	426	32.9	32.3	1.1	[16.8]	457	93.5	5.1	0	0	17	201
16	54	CTA. ECSA (1988) aliment 51	Bambara nuts fresh shelled	10.0	1446	346	19.0	6.2	57.0	[4.8]	62	12.0	2.2	0	0	1	10
17	384	Barikmo et al (2002)	Beans white dried	8.9	1150	275	22.1	1.5	46.1	10.3	82	5.7	3.8	x	0	15	179

18	74	CTA. ECSA (1988) aliment 54	Coconut matûre kernel fresh	43.0	1639	392	3.6	39.0	7.0	[6.6]	21	2.5	1.1	2	0	1	13
19	57	CTA. ECSA (1988) aliment 56	Groundnut whole shelled dried	6.5	2394	572	23.0	45.0	20.0	8.5	49	3.8	3.5	0	0	0	0
20	78	FAO (1968) aliment 331	Groundnut paste	7.2	2455	587	25.0	47.2	16.5	6.2	61	6.0	3.1	0	0	0	0
21	371	Barikmo et al (2002)	Groundnut Flour whole	4.3	2328	556	26.6	46.6	8.1	9.9	41	6.1	4.0	0	0	0	0
Fish & fish products group																	
22	120	FAO (1968) aliment 1257	Catfish mudfish whole dried	20.6	1284	307	62.5	6.3	0.0	0.0	1370	3.6	2.2	1.2	32	32	0
23	99	Barikmo et al (2002)	Catfish mudfish raw	80.0	322	77	16.2	1.4	0.0	0.0	44	0.5	0.5	1	7	7	0
24	119	FAO (1968) aliment 1261	Catfish mudfish dried smoked	11.5	1600	382	77.6	8.0	0.0	0.0	88.9	2.2	3.1	0	32	32	0
25	108	Barikmo et al (2002)	Fish Smoked	5.8	1573	376	76.0	8.0	0.0	0.0	1019	16.7	3.7	0	32	32	0
26	89	FAO (1968) aliment 1447	Fish Capitain threadfin raw	78.3	344	82	19.2	0.6	0.0	0.0	10	0.3	0.5	0	2	2	0
27	142	FAO (1968)	Fish dried	14.0	1066	255	47.0	7.4	0.0	0.0	1000	4.9	3.0	0	32	32	0
Milk and milk products group																	
28	132	CTA.ECSA (1988) aliment 124	Milk cow whole fresh	85.2	335	80	3.8	4.8	5.8	0.0	145	0.0	0.5	1	27	34	80
29	1496	FAO (1968)	Milk cow whole powder	4.0	1936	463	26.0	24.0	38.0	0.0	1000	0.5	3.3	0	400	429	345
30	126	ORANA (1993)	Milk cow whole curdled	88.1	289	69	3.8	4.9	2.6	0.0	143	0.0	4.0	1	42	47	80
31	125	USDA (2001)aliment 01095	Milk canned condensed sweetened	32.2	1179	282	8.1	5.4	53.5	0.0	262	0.0	1.0	1	92	96	42
Meat poultry & eggs group																0	
32	142	CTA. ECSA. (1988) aliment 110	Beef moderatley fat raw	63.1	979	234	18.0	18.0	0.0	0.0	11	3.6	4.1	0	tr	ND	0
33	137	CTA. ECSA. (1988) aliment 111	Egg hen raw	75.0	593	142	12.0	10.0	1.0	0.0	45	2.0	1.4	0	139	140	10
34	143	CTA. ECSA. (1988)/USDA	Goat moderatelly fat raw	68.0	716	171	18.0	11.0	0.0	0.0	11	2.3	4.0	0	0	0	0
Vegetables fruits & products group																	
35	174	MRC (1996) aliment VT	Tomato bitter raw	91.0	65	15	1.3	0.1	2.5	2.3	10	0.5	0.2	8	0	39	464
36	155	SEF/SNT/UiO (2001) aliment 6.037	Cabbage raw	90.0	109	26	1.4	0.1	5.2	2.6	47	0.3	0.2	54	0	6	66
37	154	CTA (1988) aliment 64	Carrot raw	88.6	148	35	0.9	0.1	8.2	2.4	35	0.7	0.3	8	0	500	6000
38	802	IFR	Courgette zucchini	93.7	100	24	1.8	0.4	3.5	0.9	25	0.8	0.3	21	0	51	610
39	159	CTA (1988) aliment 67	Cuncumber raw	95.0	64	15	0.8	0.1	3.0	0.6	13	0.5	0.2	14	0	0	0
40	149	CTA (1988) aliment 70	Eggplant raw	90.0	125	30	1.0	0.2	6.4	[1.3]	14	1.3	0.2	9	0	1	17
41	748	IFR	Beans french green raw	90.7	137	33	1.9	0.5	5.5	2.2	36	1.2	0.2	12	0	28	330
42	200	CTA (1988) aliment 75	Lettuce raw	94.0	90	22	1.2	0.2	4.0	[0.6]	26	0.7	0.3	10	0	163	1950
43	379	Barikmo et al (2002)	Okra pods dried powder	3.3	646	154	14.0	1.6	22.4	44.7	830	32.6	4.5	11	0	19	230

44	183	CTA (1988) aliment 79	Onion shallot mature bulbs raw	88.0	159	38	1.2	0.1	8.6	[1.0]	27	0.8	0.3	11	0	0	0
45	161	CTA (1988) aliment 83	Pumpkin squash raw	92.6	99	24	1.0	0.1	5.0	[0.8]	25	0.6	0.3	8	0	56	666
46	834	IFR	Sweet pepper green raw	93.3	65	16	0.8	0.3	2.6	1.6	8	0.4	0.1	120	0	22	265
47	201	CTA (1988) aliment 87	Tomato raw	93.5	87	21	1.0	0.2	4.0	[0.6]	10	0.6	0.1	26	0	32	380
48	147	SEF/SNT/UiO (2001) aliment 6.038	Garlic raw	64.0	535	128	7.9	0.6	24.2	1.5	19	1.9	1.0	17	0	0	0
49	185	IT(1998) (page 189)	Onion dried	4.5	1311	313	10.2	1.7	68.6	13.0	220	2.6	1.7	33	0	7	85
50	185	IT(1998) (page 189)	Shallot fried dried	4.4	1273	304	9.9	1.7	66.5	12.6	213	2.5	1.6	32	0	7	82
51	192	FAO (1968) aliment 741	Pepper hot raw	87.4	168	40	1.1	0.1	9.3	1.8	5	1.2	0.3	40	0	28	330
Fruit																	
52	153	CTA (1988) aliment 91	Banana ripe raw	77.0	343	82	1.5	0.1	20.0	[0.9]	9	0.05	0.2	9	0	8	90
53	163	IT (1998) (page 369)	Dates dried	17.3	1058	253	2.7	0.6	63.1	8.7	69	2.7	0.4	0	0	3	30
54	180	CTA (1988) aliment 98	Mango ripe raw without skin	82.9	253	60	0.6	0.2	15.0	2.6	12	1.2	0.1	42	0	200	2400
55	179	CTA (1988) aliment 92	Citrus/ orange raw	88.0	170	41	0.6	0.1	10.0	2.2	28	0.1	0.1	46	0	19	230
56	187	CTA (1988) aliment 100	Papaya ripe raw	91.0	120	29	0.4	0.1	7.0	[0.3]	21	0.6	0.1	52	0	25	300
57	199	FAO(1968)aliment 941+Bamako 2002	Saba fruit raw	21.7	1029	246	1.0	1.3	61.4	[0.8]	51	1	ND	48	0	0	0
Green leaves group																	
58	207	CTA (1988) aliment 59	Amaranth leaves raw	84.0	194	46	4.6	0.2	7.0	[1.8]	410	8.9	6.7	50	0	192	2300
59	377	Barikmo et al (2002)/Nordeide (1996)	Baobab leaves dried	6.6	508	121	12.8	4.1	8.9	42.9	2630	85	1.7	2	0	500	6000
60	383	Barikmo et al (2002)	Bean leaves raw	86.2	177	42	4.1	0.4	6.0	2.4	1130	5.3	0.5	48	0	429	5142
61	378	Barikmo et al (2002)	Fakouhoye leaves dried	6.3	745	178	22.2	2.8	17.1	34.8	1470	40.2	2.5	3	0	1025	12300
62	227	CTA (1988) aliment 74	Green leaves dark raw	80.0	244	58	4.5	0.3	10.0	[2.0]	360	7.2	0.5	80	0	275	3300
63	241	IT (1998) (page 277)	Mint leaves raw	84.9	173	41	3.8	0.7	5.3	5.6	210	9.5	0.9	31	0	62	740
64	382	Barikmo et al (2002)	Shallot leaves raw	91.0	107	26	1.9	0.3	4.0	2.0	557	4.1	0.2	23	0	573	6871
65	222	CTA (1988) aliment 85	Sweet potato leaves raw	83.0	210	50	4.6	0.2	8.0	[2.4]	160	6.2	0.3	70	0	218	2620
66	393	USDA (2001) aliment 11143	Celery leaves raw	94.6	48	12	0.8	0.1	2.0	1.7	40	0.4	0.1	7	0	3	40
67	239	IT(1998) (page 267)	Bay laurel leaves dried	5.4	1206	288	7.6	8.4	48.6	26.3	830	43	3.7	0	0	309	3710
68	912	IFR	Parsley leaves raw	83.1	178	42	3.0	1.3	5.0	5.0	200	7.7	0.7	190	0	337	4040
Fat and sugar group																	
69	1145	USDA (2007) aliment 01145	Butterwithout salt	17.9	3070	733	0.8	81.1	0.1	0.0	24	0	0.1	0	671	879	2499
70	250	USDA (2001) aliment 04042	Peanut oil	0.0	3767	900	0.0	100.0	0.0	0.0	0	0	0	0	0	0	0
71	268	SEF/SNT/UiO (2001) aliment 8.009	Mayonaise 80% fat	16.0	3073	734	1.2	80.0	2.5	0.0	10	0.5	0.1	0	42	43	9

72	252	CTA (1988) aliment 138	Red palm oil stale	1.0	3729	891	0.0	99.0	0.0	0.0	6	0	0	0	0	1000	12000
73	249	FAO (1968) aliment 1060	Shea butter	0.0	3763	899	0.0	99.9	0.0	0.0	0	0	0	0	0	0	0
74	257	SEF/SNT/UiO (2001) aliment 9.002	Sugar	0.0	1569	375	0.0	0.0	100.0	0.0	1	0	0	0	0	0	0
Condiment & spices group																	
75	262	USDA (2001) aliment 06076	Cube maggi/jumbo powder	3.3	693	166	17.3	4.0	16.1	0.0	60	2.2	0.2	0	15	15	0
76	398	SEF/SNT/UiO (2001) aliment 12.008	Mustard canned	6.0	435	104	6.4	0.3	20.2	1.7	95	1.8	1	0	0	0	0
77	273	Barikmo et al (2002)	Potassium solid	8.6	9	2	0.5	0.0	0.0	ND	38	ND	0.3	ND	0	0	0
78	235	Nordeide et al (1996)	Tamarind seeds fruit dried	5.0	1201	287	8.2	2.4	62.0	19.1	244	3	2.3	6	0	0	0
79	279	SEF/SNT/UiO (2001) aliment 6.079	Tomato paste concentrate	72.0	379	91	4.5	0.2	18.9	3.6	27	3.5	0.7	4	0	105	1260
80	281	USDA (2001) aliment 02048	Vinegar	93.8	93	22	0.0	0.0	5.9	0.0	6	6	0	0	0	0	0
81	60	FAO (1968) aliment 420	Hibiscus seed fermented	10.5	1437	343	21.4	20.3	20.0	[21.9]	320	4.2	0.6	tr	0	ND	ND
Drinks & others group																	
82	277	SEF/SNT/UiO (2001) aliment 13.003	Soft drink coke Fanta orange	90.0	157	38	0.0	0.0	10.0	0.0	0	0	0	0	0	0	0
83	1291	TACAM Recettes de Kayes	Ginger juice +sugar	82.6	270	65	0.1	0.1	17.0	0.1	1	0.2	0	0	0	0	2
84	1293	TACAM Recettes de Kayes	Lemon juice +sugar	83.7	245	59	0.1	0.0	15.5	0.0	1	0	0	5	0	0	2
85	1292	TACAM Recettes de Kayes	Orange juice +sugar	90.3	150	36	0.1	0.0	9.4	0.0	3	0.1	0	7	0	1	11
86	1128	McCanc& Widdowson's (1991)	Pineapple juice	87.8	338	81	0.3	0.1	21.0	tr	8	0.2	0.1	11	0	1	8
87	1290	TACAM Recettes de Kayes	Red guinea sorrel bouillie +sugar	86.0	214	51	0.2	0.0	13.3	0.3	22	0.4	0	2	0	3	39
88	264	Barikmo et al (2002)	Water	100.0	0	0	0.0	0.0	0.0	0.0	0	0	0	0	0	0	0
89	259	SEF/SNT/UiO (2001) aliment 9.022	Candy Sweeties	3.0	1529	365	3.0	0.0	94.2	0.0	89	1.1	0.1	0	0	0	0
90	269	USDA (2001) aliment 14214	Coffea instant dried	3.1	868	207	12.2	0.5	41.1	0.0	141	4.4	0.4	0	0	0	0
91			Cowpea mature dried*	10.9	1354	324	23.7	1.8	56.7	9.5	83	8.8	4.7	1.3	0	1.5	18

Values evaluated by Doets are writing in bleu & bold green

The sign X means values which need to be discussed nutrients

Tr = trace ND = Not determined

Values of crude fiber are presented between ( )

*: Average value of cowpea black eye dried from McCance & Widdowson's (1991) and cowpeas common (blackeyes crowder southern) mature seeds raw from USDA (2007)