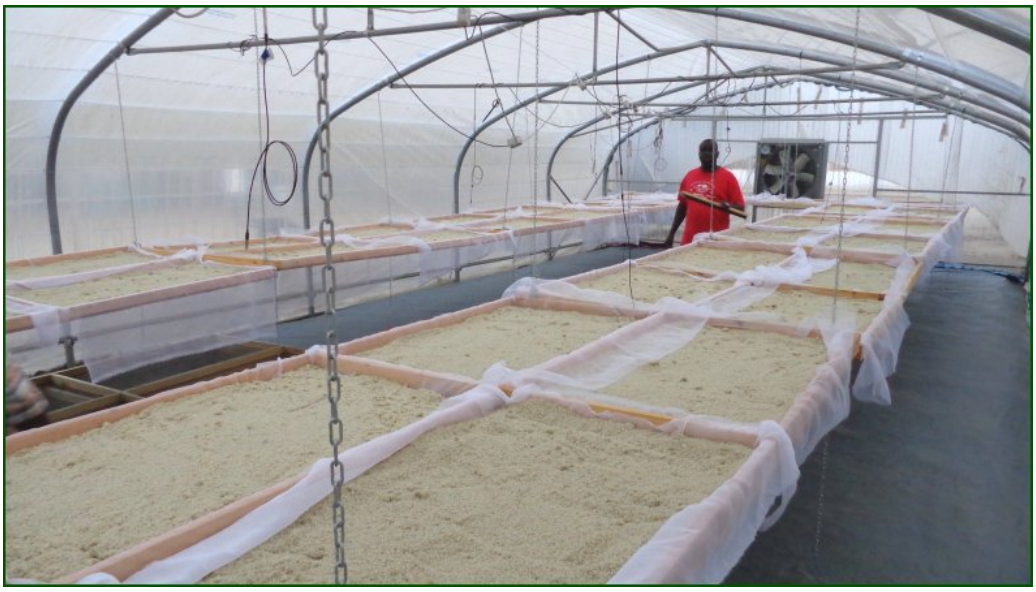
Contract AURG/161/2012

Project n° AURG/2/161

Aval Fonio

Improvement of post-harvest and enhancement of fonio in Africa

Final scientific and technical report



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Start date: 17 December 2012
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Improvement of post-harvest and enhancement of fonio in Africa

Final scientific and technical report

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November 2016

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Cover photo: Fonio drying in a greenhouse solar dryer *CSec-S* in Senegal (© M. Rivier, Cirad)

Contents

1. Description

1.1. Name of beneficiary of grant contract:

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1.4. Title of the Action:

Improvement of post-harvest and enhancement of fonio in Africa ("Aval Fonio")

1.5. Contract number: AURG/161/2012

1.6. Start date and end date of the Action:

17 December 2012, 16 June 2016

1.7. Target countries or regions:

Guinea, Mali, Burkina, Senegal (and Burundi)

1.8. Final beneficiaries and/or target groups[1]:

Final beneficiaries: African fonio commodity chain stakeholders, especially women

Target groups: Producers from Fouta Djallon (Guinea) – Women's processing groups and SMEs in Burkina Faso, Mali and Senegal - Local equipment manufacturers. National Research Systems in Guinea, Mali, Burkina Faso, Senegal (and Burundi)

1.9. Countries in which the activities take place (if different from point 1.7):
Guinea, Mali, Burkina, Senegal

[1] Target groups" are the groups/entities who will be directly positively affected by the project at the Project Purpose level, and "final beneficiaries" are those who will benefit from the project in the long term at the level of the society or sector at large.

1.10. Action structure

The Action, which is based the complementarity of the partners and their knowledge of the fields of operation, is organised in 5 *work packages* (WPs), described in detail below, and illustrated schematically in Figure 1, which also shows the target groups.

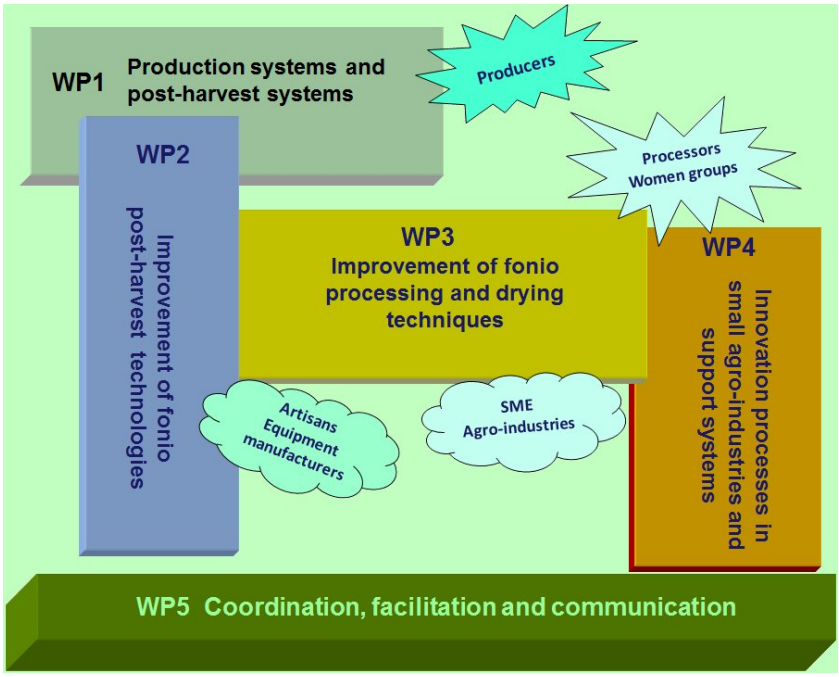


Figure 1. Work packages schematic

The main activities are illustrated in the diagram below (Figure 2).

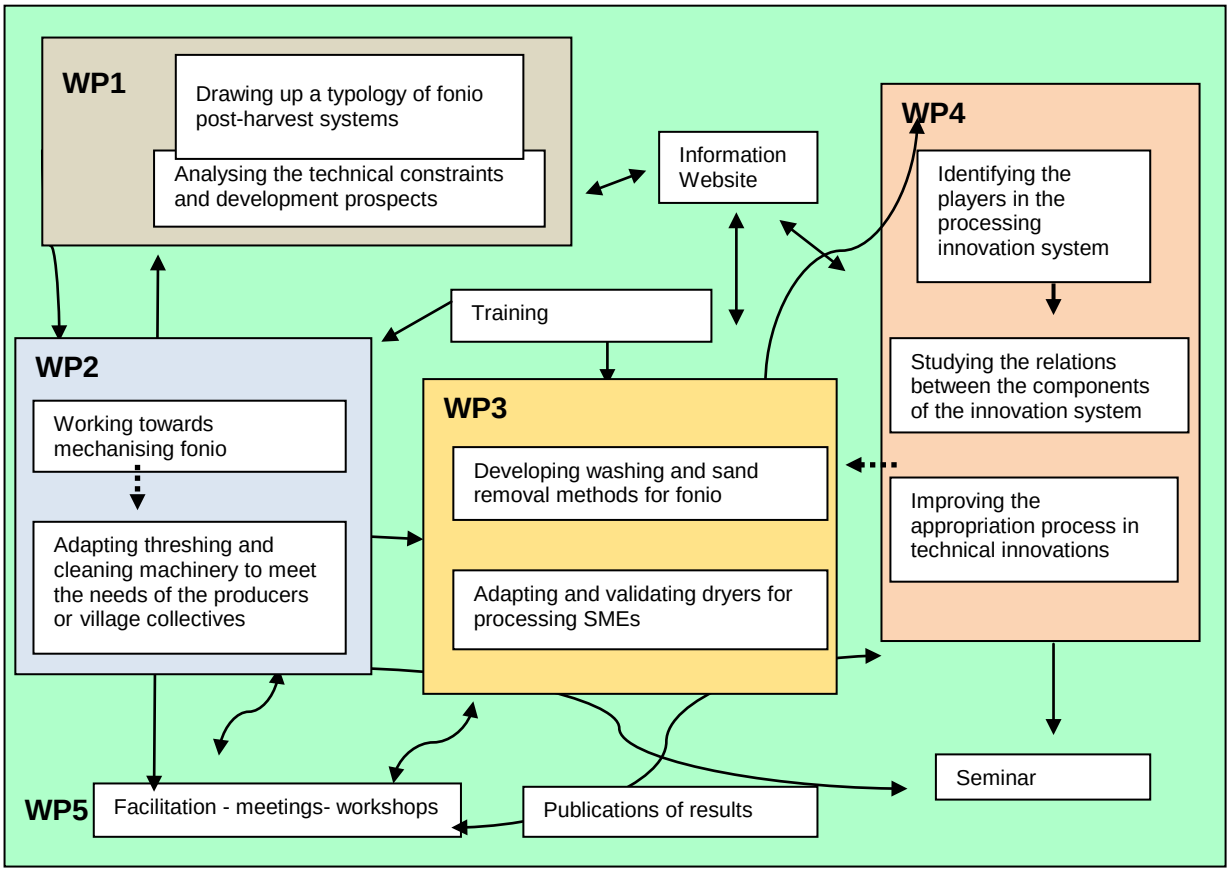


Figure 2. Diagram of the main activities of the Action

2. Assessment of implementation of Action activities

2.1. Executive summary of the Action

The Aval Fonio project (AURG/161/2012) ratified by the African Union in Addis Ababa on 17 December 2012 for a 36-month term was extended by 6 months to 16 June 2016 (African Union addendum no.1 of 5 October 2015 changing the project term to 42 months). Initially planned for Guinea, the actual project launch took place in Senegal in April 2013. The project closure was held in France in June 2016.

The activities of WP1 "*Analysis of production and post-harvest systems*" were carried out in Guinea in 7 prefectures of Fouta Djallon, where fonio cultivation is very frequent in outfields, but also in *tapades*. The study sites are mainly situated on plains and hillsides, or in the mountains. In every village concerned which are home to tens of thousands of people (with women in the majority), fonio is the main crop in terms of surface area, with more than 75 % of cultivated area. It is followed by rice and maize, but also the potato, cassava and peanut. Fonio is the second placed crop in the diet of the populations, behind rice but far ahead of maize. Over the course of the project, the producers reported an increase in fonio production, and emphasised the crucial needs in terms of mechanisation of post-harvest operations.

For WP2 "*Mechanisation of fonio post-harvest techniques*", the tests performed on various threshing equipment confirmed the good results obtained with the ASSI thresher (throughput 250 to 300 kg/h), while those of the other threshers including the standard Ricefan (Votex) thresher were mediocre. The cleaning tests validated the good performance of cleaners such as the winnowing channel, rotary screen and winnower, which were able to obtain throughputs of nearly 400 kg/h. Finally, the trials on a fonio motor mower proved unsatisfactory, and further research will be required to achieve mechanisation of fonio harvesting.

Regarding WP3 "*Improvement of fonio processing and drying techniques*", and activity 3 relating to mechanisation of washing and degritting, it was shown that washing could be mechanised using a simple electrical "cement mixer". For degritting, the "*hydrolift*" prototype degritter designed by Cirad and installed on the premises of various small companies in Mali, Burkina Faso and Senegal, has good technical performances: a throughput of 80 to 100 kg/h with a residual grit rate in fonio which can be less than 200 mg/kg. It has proven satisfactory to the users. Regarding activity 4 "drying", the *cross-flow dryer (CSec-T)* and *greenhouse dryer (CSec-S)* were tested at a station in Senegal. The *CSec-T* dryer has a load capacity of approximately 100 kg and a drying throughput of 30 to 35 kg/h (wet fonio drying from 35% to 10%). A 90 m² *CSec-S* dryer equipped with 10 trays is able to dry approximately 300 kg of fonio in 24 h (drying wet fonio from 35% to 10%). Some of these dryers, already validated in Mali by a previous fonio project, were transferred to and validated in the field in Senegal (*cross-flow* and *greenhouse* dryers), in Burkina Faso (*cross-flow* dryers) and Guinea (small *greenhouse* dryer).

For WP4 "The innovation process in small processing plants", the work conducted helped further knowledge of the key players and stakeholders of the fonio industry innovation system in Burkina Faso and Mali. The "*GMBF huller*" innovation study revealed significant impacts of technological innovation on the industry as a whole, and has been informative about the running of innovation projects and the conditions promoting the appropriation of the research results by agribusiness companies. A multi-player platform was set up in Bobo Dioulasso (Burkina Faso) to support the dissemination of the *hydrolift* degritter and the *CSec-T* dryer. This system was put together by 2 dryer manufacturers, fonio processors (RTCF network), the small fonio processing company (UTF), the NGO APROSSA-Afrique Verte and the Aval Fonio project researchers.

For WP5, the Coordination organised the kick-off meeting in Dakar (Senegal), four researchers' workshops and three annual meetings of the Steering Committee in various countries, and the final meeting in Montpellier (France). The project website (http://aval-fonio.cirad.fr/en) was launched in June 2013 and is regularly updated. The coordination also published the book "Fonio, an African cereal" (Cirad –IRAG publication) and produced a short documentary film titled "fonio".

Résumé de l'Action

Le projet Aval Fonio (AURG/161/2012) signé à l'Union Africaine à Addis Abeba le 17 décembre 2012 pour une durée de 36 mois a été prolongé de 6 mois jusqu'au 16 juin 2016 (addendum n°1 de l'Union Africaine du 5 octobre 2015 portant la durée du projet à 42 mois). Initialement prévu en Guinée, le lancement effectif du projet a eu lieu au Sénégal en avril 2013. La clôture du projet a eu lieu en France en juin 2016.

Les activités du WP1 « *Analyse des systèmes de production et des systèmes post-récolte*» ont été réalisées en Guinée dans 7 préfectures du Fouta Djalon où la culture du fonio est très fréquente dans les champs extérieurs mais aussi dans les tapades. Les sites de l'étude se situent en majorité dans des plaines et sur les coteaux ou en montagne. Dans tous les villages concernés où vivent plusieurs dizaines de milliers de personnes (dont une majorité de femmes), le fonio est la principale culture en termes de superficie avec plus de 75 % des surfaces cultivées. Il est suivi du riz et du maïs mais aussi de la pomme de terre, du manioc et de l'arachide. Dans l'alimentation des populations, le fonio occupe la deuxième place après le riz mais loin devant le maïs. Au cours du projet, les producteurs ont signalé une augmentation de la production de fonio et ont souligné les besoins cruciaux en mécanisation des opérations post-récolte.

Pour le WP2 « *Mécanisation des techniques post-récolte* », les tests réalisés sur différents équipements de battage ont confirmé les bons résultats obtenus avec la batteuse ASSI (débit de 250 à 300 kg/h) alors que ceux des autres batteuses, dont la batteuse type Ricefan (Votex), ont été médiocres. Les tests de nettoyage ont validé les bonnes performances des nettoyeurs comme le canal de vannage, le crible rotatif et le tarare qui ont permis d'obtenir des débits proches de 400 kg/h. Enfin, les essais d'une motofaucheuse à fonio n'ont pas donné satisfaction et des recherches sont encore nécessaires pour aboutir à une mécanisation de la récolte du fonio.

Concernant le WP3 *« Amélioration des techniques de transformation et de stabilisation* », et l'activité 3 de mécanisation du lavage et du dessablage, il a été montré que l'utilisation d'un simple laveur type «bétonnière» électrique permettait de mécaniser le lavage. Pour le dessablage, le prototype de dessableur « *hydrolift* » conçu par le Cirad et installé dans différentes petites entreprises au Mali, au Burkina Faso et au Sénégal, a de bonnes performances techniques: débit de 80 à 100 kg/h avec un taux de sable résiduel dans le fonio qui peut être inférieur à 200 mg/kg. Il a donné satisfaction aux utilisateurs. Concernant l'activité 4 « séchage », les séchoirs à *flux traversant (CSec-T)* et *serre solaire (CSec-S)* ont été testés en station au Sénégal. Le séchoir *CSec-T* a une capacité de chargement d'environ 100 kg et un débit de séchage de 30 à 35 kg/h (séchage de fonio humide de 35% à 10%). Un séchoir *CSec-S* de 90 m² équipé de 10 claies assure le séchage d'environ 300 kg de fonio en 24 h (séchage de fonio humide de 35% à 10%). Certains de ces séchoirs, déjà validés au Mali lors d'un précédent projet fonio, ont été transférés et validés en milieu réel au Sénégal (séchoirs à *flux traversant* et *serre solaire)*, au Burkina Faso (séchoirs à *flux traversant*) et en Guinée (petit séchoir *serre solaire*).

Pour le WP4 « *Processus d'innovation dans les petites industries de transformation* », les travaux réalisés ont permis d'approfondir la connaissance des acteurs clés et des parties prenantes du système d'innovation de la filière fonio au Burkina Faso et au Mali. L'étude de l'innovation « *décortiqueur GMBF* » a révélé des impacts significatifs de l'innovation technologique sur l'ensemble de la filière et renseigne sur la conduite des projets d'innovations et les conditions qui favorisent l'appropriation des résultats de la recherche par les entreprises agroalimentaires. Une plateforme multi-acteurs a été mise en place à Bobo Dioulasso (Burkina Faso) afin d'accompagner la diffusion du dessableur *hydrolift* et du séchoir *CSec-T*. Ce dispositif a été constitué par 2 fabricants de séchoirs, des transformatrices de fonio (réseau RTCF), la petite entreprise UTF, l'ONG APROSSA-Afrique Verte et des chercheurs du projet Aval Fonio.

Pour le WP5, la coordination a organisé la réunion de démarrage à Dakar (Sénégal), quatre ateliers de chercheurs et trois réunions annuelles du comité de pilotage dans différents pays et la réunion finale à Montpellier (France). Le site Web du projet (http://aval-fonio.cirad.fr/) a été mis en ligne dès juin 2013 et régulièrement actualisé. La coordination a publié l'ouvrage «Fonio, an african cereal» (publication Cirad – IRAG) et a produit un petit film documentaire intitulé « Fonio ».

2.2. Activities and results

2.2.1. WP1: Analysis of production and post-harvest systems

Activity 1.1. *Typology of production systems and associated post-harvest systems*

This activity was coordinated by Dr Béavogui Famoï (IRAG), and carried out by IRAG agents under the supervision of Mr. Camara Sawa and the intern Ms. Diallo Aïssatou.

✓ ***Surveying***

The surveys were conducted in 7 prefectures of Fouta Djallon, where fonio cultivation is very frequent in outfields, but also in *tapades*[2]. The surveys were conducted on farms in 11 villages, for the most part situated on the hillsides, though also on the plains or in the mountains.

Table 1. List of prefectures and villages surveyed

Prefecture	Village	Eco-zone
Mamou	Bouliwel	Mountains
Dalaba	Mitty	Hills
Pita	Hafia, Timbi-Touni	Plains
Labé	Daaralabé, Sèghen	Hills
Lélouma	Lélouma urban community and Diountou	Hills
Koubia	Pilimini	Hills
Mali	Donghel Sigon and Fougou	Plains and mountains

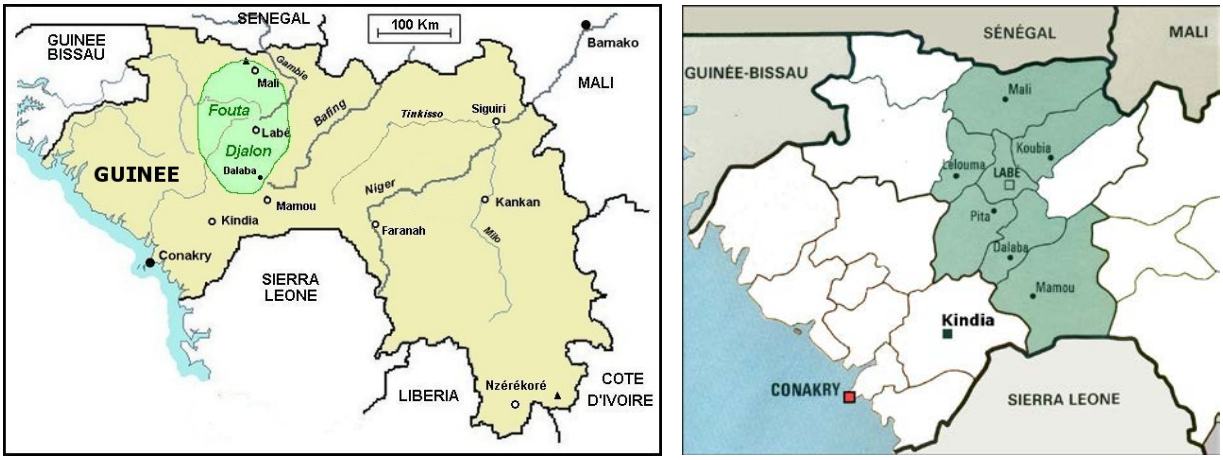


Figure 3. Map of Guinea and the surveyed prefectures in Fouta Djallon

✓ ***Survey results***

- "Tapades" or family gardens, also known as *Sunturè* in the Guinean language pular, are enclosed cultivated areas. They are the special preserve of the women, who use them above all to grow vegetables and fruit trees. In most villages, fonio cultivation under this system generally remains very limited, and relegated to the edges of enclosures, or within tapades under preparation. Yet in the Lelouma and Mali prefectures, fonio is commonly cultivated in this part of the farms, as it is present in 50% of cases. Fonio is sown there upon the first rains with extra-early varieties (80 to 90 days), such as *Yaoukoh*, to ensure for the "lean season" a harvest intended for self-consumption. This early harvest suffers from drying problems since it is performed in the rainy season (August – September). In the "tapade system", as soon as soil fertility has been restored in the plots, fonio cultivation is often abandoned in favour of maize or other food crops (taro, sweet potato, vegetables).

[2] Tapade: An enclosure within a farm in Fouta-Djallon, Guinea. The word tapade is a Franco-Guinean term, apparently derived from the Portuguese *tapar:* close.

Figure 4. Early fonio within a tapade in Mali prefecture (© S. Camara, IRAG)

- “Outfields”, which are most often the prerogative of the men, are often used for cultivating fonio since they represent nearly 60 % of cultivated surface areas. The other crops frequently grown are dry-land rice, peanut, maize, cassava or potato. In the Lelouma and Mali prefectures, the “outfields” are frequently cultivated by women (45% of smallholders), who have taken over the farms because of the large-scale migration of the men toward Guinea’s mining zones (Fria, Kamsar, Siguiri etc.), Senegal, Europe or even the United States.

There are three distinct types of farm by ecological zone: plain fonio, hillside fonio and mountain fonio.

Plain fonio

The plains are homogeneous expanses of grassy vegetation on acidic soils (pH<5), poor in organic matter. These types of soil are common in the Pita and Dalaba prefectures, and in certain zones of Labé prefecture.

The surveys showed that plain fonio is cultivated on 60% of the surveyed farms. On these farms, which have an average surface area of 2 ha, the producers sow extra-early varieties (80 to 90 days) and medium-late varieties (110-130 days) such as *Siragbé*, *Rané* and *Konso*. The sowing, carried out in June & July in average quantities of 50 kg/ha, is followed by weeding, generally with 2 in August and September. The harvests are then staggered from October to November, with yields of more than 600 kg/ha. This ecology, on poor soil, is characterised by fonio monoculture for 5 to 10 years followed by a fallow period of equivalent duration.

An exemplary case of plain fonio cultivation is provided by the village of Donghel Sigon (Mali prefecture), which harnesses two large enclosed areas of 170 ha and 250 ha. These spaces, previously used for growing potatoes, are now dedicated to fonio cultivation. The potato was recently abandoned because of difficulties of irrigation, and of access to inputs and the market.

Figure 5. Plain fonio in the village of Donghel Sigon (© S. Camara, IRAG)

The ploughing, sowing, weeding, harvesting and threshing work are mainly manual, and require a significant external workforce (mutual assistance or employing casual labourers). It is mainly for plain fonio that harvest mechanisation is most feasible.

Hillside fonio

This system is characterised by well-drained gravelly soils where fonio is cultivated alongside peanut, cassava and rice. It is present on 35 % of surveyed farms. On farms with a surface area of 1 to 2 ha, the producers sow the fonio after growing rice for one or two years.

After working the soil in June, fonio is sown in July in average quantities of 40 kg/ha, followed by manual weeding only, often carried out by the women. Because of the low water retention capacity of the soil, the producers use extra-early varieties (80 to 90 days) such as *Wouleman* or *Yaoukoh*, which thereby ensure a harvest in the "lean" season.

The harvests are staggered from August to October, with yields of around 700 kg/ha. Mechanisation of ploughing and harvesting is a difficult proposition, because of the presence of stones and tree stumps in the fields.

Figure 6. Hillside fonio (© S. Camara, IRAG)

Mountain fonio

This system is characterised by steep terrain which has been cleared (slash-and-burn clearing from February to April) for growing dry-land rice, peanut, sorghum and fonio. Rice is always the first rotation crop, often followed by fonio from the second year.

On farms with an average surface area of around 1 ha, the producers sow extra-early varieties (80 to 90 days) and medium-late varieties (110-130 days). Sowing is carried out in June & July in average quantities of 30 kg/ha. The harvests are then staggered from August to October, with average yields of 900 kg/ha or even 1000 kg/ha.

Figure 7. Mountain fonio in the village of Bouliwel (© S. Camara, IRAG)

As with the hillside fonio, mechanisation of ploughing and harvesting is a difficult proposition because of the steep slopes and the presence of stones and tree stumps in the fields. Because of the heavy constraints on field work, this ecology zone is dominated by men.

✓ ***Main observations***

Crop rotation

Whatever the ecology in the outfield system, producers apply crop rotation. Table 2 below sets out the main crop rotation systems for the surveyed farms.

Table 2. Crop rotation systems by ecology

Ecology	Rotation systems
Plain	Fonio on fonio for more than 10 years followed by fallow Potato – rice – fonio Potato – maize – peanut – fonio
Hillside	Rice – rice – peanut – fonio followed by fallow Rice – peanut – fonio – fonio followed by fallow Fonio – cassava – peanut – fonio followed by fallow
Mountain	Rice – rice – fonio followed by fallow Rice –fonio – fonio followed by fallow Rice – peanut – fonio followed by fallow

Cultivation calendar

In these ecological zones, fonio cultivation is a traditional, primarily manual activity.

Table 3. Cultivation calendar by ecology

Ecology	Cultivation operations				
	Clearing, slash-and-burn, clean-up	Labour	Semis	Weeding	Harvest
Plain	May	June- July	July - August	August to September	October to December
Hillsides	April - May	May - June	June	August	August to October
Mountains	February to April	May - June	June	August	August to October

Varieties

The most commonly used varieties are the extra-early varieties (70 to 90 days) and medium-late varieties (110-130 days)[3]. The main varieties encountered are *Wouléman*, *Yaoukoh*, *Siragbè*, *Ranè* and *Konso*. The criteria for variety selection by producers are earliness, seed availability, ease of hulling and high yield. On the farms, the majority of producers say that they have abandoned at least one or two varieties such as *Bambougou*, *Boléfondé*... because of their overly long cycle, and the threshing and hulling difficulties that they cause.

Gender aspect

In the Lélouma and Mali prefectures, the women are heavily involved in outfield fonio cultivation, unlike in the other prefectures, where the "outfield" production system remains dominated by men. These women are generally the wives of men away from home, because of the high migration among this social stratum.

Destination of fonio (self-consumption, trade)

In most of the surveyed zones, the staple of household diet remains rice (local and/or imported), though fonio does have a significant share, varying from 30 to 40 %. Nonetheless, in mountainous zones and in Lelouma and Mali prefectures, fonio consumption is often greater than for rice.

Fonio is mainly aimed at family self-consumption and sowing, yet part of the harvest can sometimes be sold to support the families' monetary needs for purchasing food, clothing or their children's education. This is the case in particular with farms with fields of more than 1 ha, which sell 40 to 50 % of their production upon harvesting. In the Lélouma and Mali regions, fonio is often sold to wholesalers from Senegal.

[3] According to the classification defined in the book "Fonio, an African cereal" (Cruz & Béavogui, 2011)

Activity 1.2. *Main producer constraints, and prospects*

The main difficulty reported by fonio producers concerns the complete absence of a concerted strategy between the public services and fundamental players. They lament the lack of structuring of the industry, due to which they often feel abandoned without entitlement to technical or financial support. The other main constraints encountered by producers and identified in the surveys concern on the one hand those due to production and on the other hand those relating to the harvest and post-harvest.

✓ ***Production constraints***

The main constraints reported by producers in terms of fonio cultivation relate firstly to soil quality. On the plains, the soils are regarded as very poor because of fonio monoculture for 5 to 10 years in succession. In the hillside and mountain zones, cultivation is made difficult by the steepness of the terrain and the presence of stones.

Weeds, attack by birds or wild animals (monkeys), but above all the presence of termites, are constraints frequently mentioned by fonio producers.

Degenerescence of varieties is also a factor which contributes to limiting fonio cultivation. According to certain producers, the seeds used now produce only low yields, and nearly 80% say that they have abandoned the late varieties with more than 130 days' vegetation.

In view of the lack of family labour (high migration by young people) and the high maintenance workload (ploughing, weeding, etc.), producers had a lot of complaints about the dilapidation of the agricultural tools and the low level of agricultural mechanisation.

Finally, the long distances to travel between villages and outfields on poorly maintained rural tracks represent a brake to the development of fonio cultivation.

✓ ***Harvesting constraints***

On all the farms, fonio harvesting is still an exclusively manual operation. It is often performed using rudimentary tools such as the sickle or knife.

1- Sickle

2 – Knife

Figure 8. Fonio harvesting tools (© S. Camara, IRAG)

According to producers, manual harvesting, sometimes performed by women, remains a highly painstaking operation, especially because of lodging of fonio upon maturity (figure 9). Furthermore, transport and stacking of the sheaves before threshing (figure 10) reportedly cause significant but unevaluated losses. These various constraints are leading certain producers to reduce the cultivated surface areas, or even abandon fonio cultivation.

Figure 9. Harvesting by sickle (© S. Camara, IRAG)

Figure 10. Stack of sheaves (© S. Camara, IRAG)

✓ ***Post-harvest constraints***

In the surveyed villages, threshing which consists in separating the grains from the panicles is generally performed by trampling or crushing underfoot (figure 11). Supporting themselves on a horizontal bar or on rods, the women or children rub the sheaves one by one between their feet to separate the grains from the stem.

Figure 11. Fonio threshing by crushing underfoot (© S. Camara, IRAG)

Yet the producers, especially the women, still consider the most painstaking and the most loss-causing operation to be hulling-whitening, which remains to this day the main bottleneck for the industry. Indeed, traditional hulling, carried out using a pestle and mortar by women, is highly unproductive, with just a few kilogrammes of paddy fonio processed per hour.

Note: Under the Aval Fonio project, the producers from the village of Donghel Sigon participated in mechanical threshing trials. To promote mechanical hulling of fonio in the zone, a GMBF huller was provided.

Generally speaking, the producers lament the low level of distribution of threshing, cleaning and hulling equipment developed by research over the past decade. The absence of mechanisation of the post-harvest operations in most of the surveyed zones forces many producers to employ labour from outside the family. Yet this labour is increasingly scarce because of the high migration of young people to employment hotspots outside the region.

Under previous Fonio projects, Guinea has participated in adapting the ASSI thresher and developing cleaning equipment (rotary screen and winnowing channel) and hulling equipment (GMBF fonio huller). Yet the manufacture and distribution of all this equipment is practically non-existent in Guinea, while it is starting to become very widespread in Mali, Burkina Faso, Senegal and throughout West Africa.

- ✓ ***Trade constraints***

In Fouta Djallon, the landlocked position of the big production zones and the poor condition of the communication routes (rural tracks) are major brakes on fonio trade. They generate high transport and handling costs in taking the fonio to the villages, where the collection markets are held to supply the big market in Mitty (Dalaba prefecture). The lack of threshing equipment and processing equipment (hullers) prevents producers from trading as much hulled fonio as they would like.

- ✓ ***Prospects***

Despite the various constraints impeding producers, there are many reporting an increase in fonio production. In the surveyed regions, this positive result could be due to potato and fonio crop rotations, to following the cropping calendar or to applying longer fallow periods (5 to 10 years).

Fonio production can be improved by implementing rational cultivation techniques, with in particular a choice of varieties tailored to the ecological zones and to consumer preferences, good soil preparation with possible use of inputs and finally following a cropping calendar with good crop rotations.

Improving rural transport should also enable producers to increase their quantities traded on the collection markets.

Yet the most important factor is definitely the development of harvest mechanisation (where possible, such as on the plains zone) and mechanisation of post-harvest operations such as threshing, cleaning and hulling-whitening. Better recognition of the industry by institutional and financial support should help encourage the various operators to earn better value from this cereal, which is an icon of Guinea.

2.2.2. **WP2: Mechanisation of fonio post-harvest techniques**

The various actions carried out under this work package were under the responsibility of Thierno Alimou Diallo (IRAG) and Patrice Thaunay (Cirad), co-supervisors of WP2, with the collaboration of Ousmane Tanou Bah (IRAG).

Activity 2.1. *Mechanising the harvesting of fonio*

A motorised rice mower, manufactured in Guinea, underwent a minor modification on the cutting bar by way of adaption to fonio. The field tests performed in Guinea demonstrated that the motor mower cuts the stems but does not discharge the sheaves on the side of the machine (figure 12). The straw gets entangled around the rotors, and causes jams (figure 13). So studies are required to address the mechanisation of fonio harvesting in the long term.

Figure12. Mechanised mowing test on a smallholding (© IRAG)

Figure13. Entangled straw (© IRAG).

Activity 2.2. *Adapting the threshers and cleaners*

✓ ***Threshers***

Tests on various threshers

Tests on various threshers (*Comfar* thresher, Chinese "hold-on" thresher, *Ricefan* thresher) were carried out in Guinea. The first two threshers (Comfar thresher and Chinese thresher) were quickly abandoned because of their low capacity. The Ricefan thresher, manufactured by the IMAF workshops in Bamako, was tested first in 2014 by the Mali IER/LTA team, before being shipped to Guinea for testing by IRAG. The threshing trials showed that the thresher was ill-suited to threshing fonio, since the most of the grains are carried through with the straw after entering the thresher-fan drum. The substandard performances of the *Ricefan* thresher (low throughput, incomplete threshing, grains mixed with straw, etc.) convinced the researchers of the need to recondition the ASSI thresher.

ASSI thresher

The ASSI thresher (Adrao, Saed, Sismar, Isra) is a rice thresher derived from IRRI axial threshers. It is in particular manufactured in Senegal by SISMAR (*Société Industrielle Sahélienne de Mécanique de Matériel Agricole et Représentation*), but also by various local tradesmen.

In a previous fonio project (CFC Fonio), an ASSI thresher was purchased and trialled by IRAG and Cirad in 2001. The performance on fonio was very good, with an average throughput varying between 250 kg/h and 300 kg/h, and an excellent threshing quality.

Under the Aval Fonio project, this ASSI thresher was reconditioned to carry out new tests. After initial workshop trials, the thresher was transported to the village of Donghel Sigon (Fouta Djallon) for a field operation demonstration trial.

Figure 14. Fonio mechanical threshing trial/demonstration in Donghel Sigon (© S. Camara, IRAG)

The ASSI thresher trials obtained an average throughput of 240 kg/h of fonio grain, equivalent to more than 600 kg/h of sheaves. It validated its good threshing performances, since the bulk of the grains was recovered at the main outlet, with less than 2% impurities. The quantity of unthreshed grains was estimated at less than 5 %. The quality of threshing was deemed highly satisfactory by the producers.

Figure 15. ASSI thresher (© S. Camara, IRAG)

Figure 16. Clean threshed grains (© S. Camara, IRAG)

Partial conclusion

The ASSI thresher is a rice thresher which may be perfectly suitable for threshing fonio, with a few modifications. This robust machine is able to obtain a threshed grain throughput of around 250 to 300 kg/h, with a very high threshing quality (few unthreshed grains, few impurities).

To evaluate the cost of motorised threshing with an ASSI thresher, a simulation was conducted, adopting the hypothesis of a tonnage of approximately 100 T of threshed fonio per year, in 90 days' operation. This simulation led to a threshing cost of approximately 15 FCFA (€0.02) per kg of threshed fonio.

Following on from the very good results obtained with the modified ASSI thresher, the mechanisation specialists have validated the machine for threshing fonio, and also take the view that it seems economically profitable, especially under conditions in Guinea. Threshers are relatively expensive machines which can often only turn a profit on a contracting basis. This equipment should be affordable to village associations or outsourcing contractors.

The current machine, a relatively bulky piece of equipment, may be suitable for easily accessible plain zones. For mountain zones, the same type of thresher would be needed, but more compact in size, to be more easily transportable.

✓ ***Cleaners***

An Alvan Blanch **winnower** (figure 17) was restored to working order by IRAG in 2013 for the purpose of paddy fonio cleaning trials. This equipment comprises a fan, a hopper and an alternating-motion cleaning unit, with two grilles mounted horizontally and a third sloping grille for eliminating particles smaller than the grains (figure 18). The grains drop out of the hopper onto the horizontal grilles, which are ventilated by a horizontal air flow produced by the fan. The straw is carried away while the grains pass through the first two grilles.

In 2014, the equipment was modified in a Labé workshop, fitted with a chassis to enable the machine to be driven by an engine. The trials conducted at IRAG Bareng in 2015 achieved a throughput of around 400 kg/h, with good cleaning quality.

Figure 17. Alvan Blanch winnower (© J-F Cruz, Cirad)

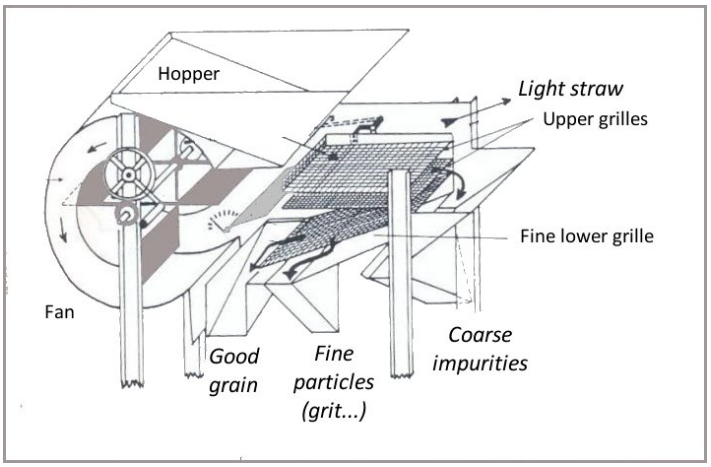


Figure 18. Diagram of a winnower (© J-F Cruz, Cirad)

A **winnowing channel** and a **rotary screen** were supplied by the project to IRAG in 2013. This equipment was designed by Cirad under the first fonio project. They were manufactured by the manufacturer IMAF in Bamako (Mali), and were delivered to the IRAG Bareng Centre in January 2014.

The winnowing channel is a piece of cleaning equipment comprising a vertical duct with air upflow, into which the dirty product to be cleaned is introduced halfway up. The light particles are carried away by the air flow, and collected in a cyclone (figure 19). The grains and heavier particles drop into the lower part of the channel. The winnowing channel can be used immediately downstream of the GMBF huller, or on its own, equipped with a removable hopper. So it is suitable for cleaning fonio, but also winnowing other cereals.

The rotary screen comprises a slightly tilted cylindrical screen with two successive grilles (figure 20). The screen is equipped with a feed hopper, and can be driven manually (crank) or by an electric motor.

Figure 19. Winnowing channel (© C. Marouzé, Cirad)

Figure 20. Rotary screen (© M. Rivier, Cirad)

The trials carried out at IRAG Bareng confirmed the good performance of the equipment, with average throughputs of around 400 kg/h.

Partial conclusion

The winnower is a classic piece of cleaning equipment ideally suited to use for cleaning fonio, employing grilles and ventilation flowrates tailored to this tiny cereal. The winnower is versatile and has the advantage of running even with straw-laden products. Its operating principle, consisting in alternating motion of the grilles, does make it delicate to use, so the more robust rotary cleaners are often preferred.

In light of the very good results obtained (throughput around 400 kg/h) with the winnowing channel and rotary screen under previous fonio projects, and confirmed by the Aval Fonio project, the mechanisation specialists have validated this equipment for cleaning paddy fonio, and take the view that it can be used for cleaning hulled and whitened fonio; the winnowing channel is also often coupled to the GMBF huller-whitener in order to clean the product after processing.

These two machines are versatile, and can be used on cereals other than fonio. Now both machines should be makeable by local tradesmen, to ensure their distribution across a range of West African countries.

2.2.3. WP3: Improvement of fonio processing and stabilising techniques

The various actions carried out under this work package were under the responsibility of Thierry Goli (Cirad), Cheikh Mouhamed Fadel Kébé (ESP-UCAD) and Ms. Bore Fanta Guindo (IER), co-supervisors of WP3.

Activity 3. *Developing washing and degritting methods for fonio*

This activity consists in designing, making and testing models for washing and degritting hulled and whitened fonio.

✓ ***Mechanisation of washing***

Washing consists in eliminating foreign particles and bran which remain stuck to the fonio grains after hulling/whitening and winnowing/screening. Hand mixing of fonio in large tubs filled with water obtains good separation of the bran and light particles which are removed with the supernatant contaminated water, while the grains and grit are collected by sedimentation.

Initial washing tests were carried out in Mali on prototype washers identified by IER. These involved a washer manufactured by the equipment maker MOD Engineering, already installed on the premises of a small fonio processing company "*Dado production*" in Bamako; and small washers provided by the tradesman Nana Philomène. The results obtained with these two washers were unconvincing, and the equipment was not validated.

The trials then switched to electrical rotary washers. The idea of using rotary washers was proposed by Cirad in conjunction with Ucodal. This “cement mixer” type equipment is actually well-suited to the mixing function required by fonio washing. Washing by means of standard rotary electrical washers was tested by Cirad in a pilot workshop in Montpellier (figure 21), and by IER on the premises of Ucodal in Bamako (figure 22). This model was chosen for its simplicity, its low cost and because it employs an excess water mixing principle similar to that employed in traditional manual washing.

Figure 21. Rotary washer at Cirad (© Cruz, Cirad)

Figure 22. Rotary washer trial in Mali (© IER)

The results obtained in 2014 were confirmed in 2015 at Cirad’s Agri-food Platform, as part of the development of the first prototype line of washing-degritting machines. A two-minute prewash, followed by a one or two-minute final wash, obtain a product with cleanliness compatible with the constraints of mechanised degritting further downstream. The level of workload is lower than for manual washing, and the work times and quantities of water necessary are also points in favour of mechanised washing.

✓ ***Mechanisation of degritting***

Degritting consists in eliminating the grit present in the whitened fonio grains by a series of separation operations performed using gourds. For this activity, the research actions related to:

- developing a method for measuring the quantity of grit in a fonio sample,
- design and laboratory trialling of a “hydrolift” model degritter,
- manufacture and field trialling of “hydrolift” prototype degritters.

➢ *Developing a method for measuring the quantity of grit in a fonio sample*

The method to identify must be sensitive within the range 0 to 3% grit, and have a quantification threshold of around 0.01% (w/w) in fonio. In fact, measurements made by counting under a binocular magnifier demonstrated that the hulled and whitened fonio before degritting contained approximately 3% grit, whereas the grit content of traditionally degritted fonio is around 0.01% (sensory measurement made on commercial fonio).

Figure 23. Grains of grit in whitened fonio (© J-F. Cruz, Cirad)

Cirad conducted a study to quantify the grit in a fonio sample. Several methods were tested:

- Calcination at 600°C (Cirad laboratory)

The method consists in calcinating the fonio, and then taking up the mixture of ash and grit in pure water. The grit is then weighed. The trials conducted demonstrated that this method was unable to assay the grit in a sample containing less than 10% grit, since below that level the ash forms a crust inseparable from the grit. This unsuitable method has been abandoned.

- X-ray diffraction (European Institute of Membranes laboratory, Montpellier)

The method consists in analysing the waves diffracted by the microcrystalline material when exposed to an X-ray beam. On the assumption that the grit primarily comprises silica crystals, analysing the density and diffraction angle of the X-rays should enable us to work out the grit content. The trials conducted demonstrated that silica is present in the form of very large crystal clusters. This configuration does not enable quantification of the silica, so the method was abandoned.

- Near-Infrared Spectrometry (NIRS), Cirad laboratory

Each wavelength of NIRS radiation (0.8 to 2.5 µm) which is aimed at the fonio sample is transmitted or reflected, depending on its composition. Processing of the spectrum obtained could, using a calibration range, be used to quantify the presence of grit, with known specific absorption and reflection properties. A first trial demonstrated the possibility of separating two groups of grit contents: only the 0 to 0.01% group can be distinguished from the 0.05 to 0.3% group, over a content calibration range of 0 to 0.3%. However, it proved that this is insufficient to classify fonio samples from the degritting model tests. These actually have grit contents of between 0 and 0.1% (w/w). A degritting result of such quality is surprising and means much more substantial trials to develop a reliable NIRS method, which would be beyond the scope of the present project.

- Silica assaying and ICP detection method (Cirad laboratory)

Methods suitable for assaying silica in plants and soils were tested. Their principle is calcination followed by acidic or alkaline digestion. The silica is then assayed by ICP (Inductively Coupled Plasma) at 1100°C. They did not yield convincing results for contents of less than 1% grit, due to the need to evaporate the hydrofluoric acid. In 2015, the analyses were reworked thanks to the acquisition of an ICP kit for direct injection of hydrofluoric acid solutions. The method of cold solubilisation with hydrofluoric acid, followed by assaying the silica by optical ICP, yielded the most consistent results (figure 24). However, for low grit contents, the silica provided by the siliceous skeleton of fonio (≈ 0.14%) may conceal the silica provided by grit. Hence the method will have low sensitivity in the grit content region of 0.01 to 0.1%. A tenfold increase in grit content will only generate an increase in silica content of 25%. However the method is potentially usable.

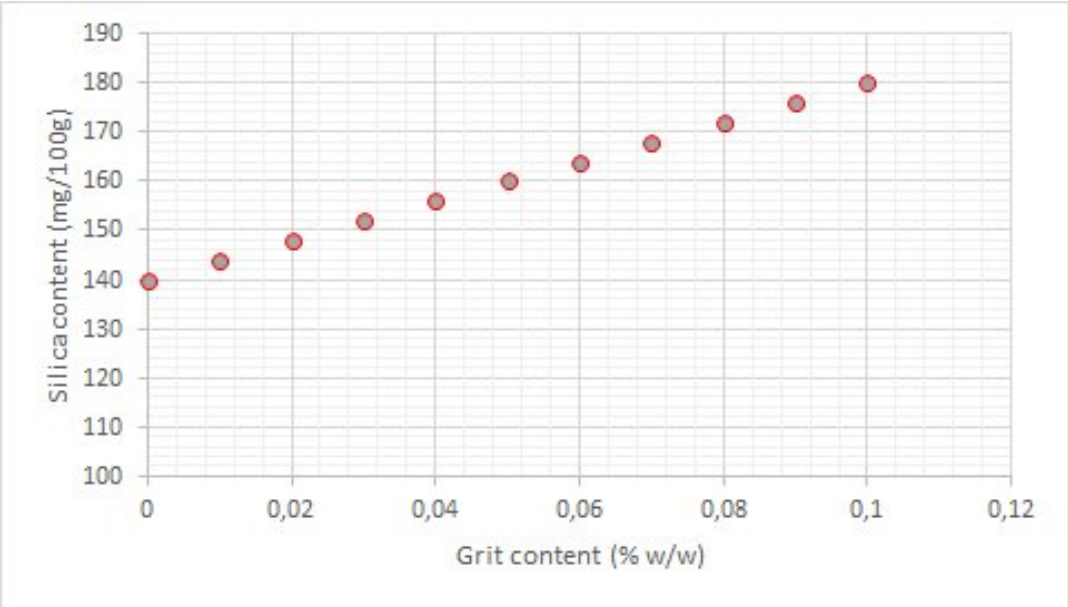


Figure 24. Silica content in 100 g of fonio, against the sample grit content (© T. Goli, Cirad)

- Silica assay method (Cirad laboratory)

Suitable methods for assaying silica in plants and soils were tested. They were based on calcination followed by acidic or alkaline digestion, of silica or organic matter respectively. The silica is then assayed by ICP (Inductively Coupled Plasma) at 1100°C. They did not yield convincing results for grit contents of less than 1%, due to the need to evaporate the hydrofluoric acid.

- Sensorial analysis method (Cirad laboratory)

This method, tested in 2014, yielded highly conclusive results. The method for determining the grit content by taste is highly sensitive, with a very low detection threshold (around zero). It is not applicable above 0.2%. It was useful for the degritting model trials at the Cirad platform in early 2015 (grit contents of 0 to 0.1%).

- Manual degritting

For analysing the quantities of residual grit obtained during the "*hydrolift*" prototype field trials, it is more efficient to perform manual degritting of the samples taken, since the local women processors are expert in separating grit from fonio.

➢ *Design and laboratory trialling of a "hydrolift" model degritter,*

Functional analysis of the degritting operation confirmed the usefulness of the principle and of the "*Hydrolift*" model already designed by Cirad in 2001 under the first fonio project. In 2013, a new hydrolift was manufactured and laboratory tested.

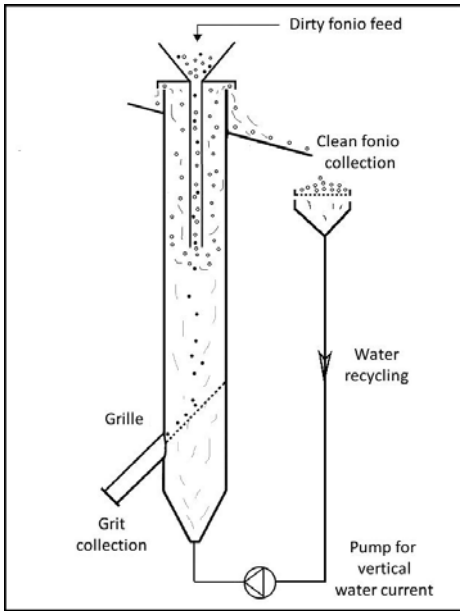


Figure 25. Schematic and model of the hydrolift (© J-F. Cruz, Cirad)

Various trials on the model were used to adjust several parameters to optimise the system hydraulics in order to homogenise the water flows in the fonio/grit separation column, and regulate the wet fonio feed.

Based on preliminary trials, an experiment plan was defined to evaluate the optimum performances of the hydrolift. It followed the protocol below:

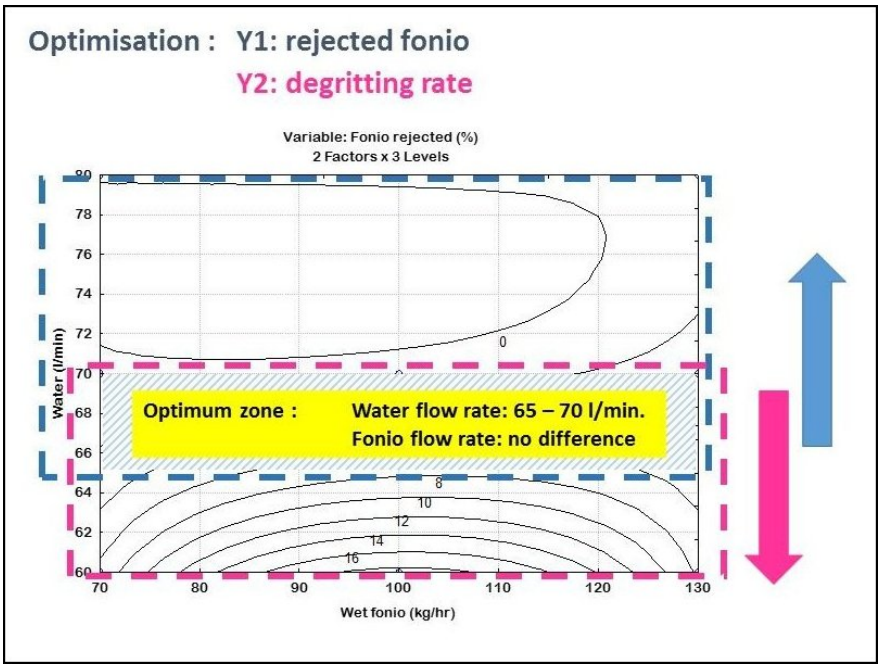
- Determining the type of plan (complete 3^2 factorial design, with repetitions of the central point)
- Determining the influential independent variables and boundaries of the experimental domain:
  - ➢ Fonio flowrate: 70 to 130 kg/h of wet fonio
  - ➢ Water flowrate: 60 to 80 l/min.
- Determining the response variables:
  - ➢ Y1 = "rejected" fonio
  - ➢ Y2 = Residual grit content in the degritted fonio

The trials were able to show the predominant effect of water flowrate in the degritting column, whereas the fonio feed flowrate had no influence on the responses, in our experimental domain. It should be noted that the main factor (water flowrate) had the following effects:

- negative on the quantity of rejected fonio (when the flowrate increases, the quantity of rejected fonio decreases)
- positive on the quantity of residual grit (when the flowrate increases, the quantity of grit in the degritted fonio increases)

Thus a compromise needs to be found, since the water flowrate factor, the hydrolift's main setting variable, has an antagonistic effect on the target objectives, namely:

- minimise the rejected fonio: blue arrow upward (figure 26)
- minimise the grit content: pink arrow downward (figure 26)



The optimum setting zones for the factors are represented by a pink dashed line for the residual grit content, and in blue for the quantity of rejected fonio.

Figure 26. Isoresponse curves: rejected fonio as a function of water and wet fonio flowrates (© T. Goli, Cirad)

Thus we can conclude that an intermediate water flowrate, of around 65 to 70 l/min, should be favoured in the prototype design to be disseminated.

A validation trial demonstrated that for a wet fonio flowrate of 130 kg per hour, and a water flowrate of 65 to 70 l/min, the following responses were obtained:

- 0.005 to 0.015% grit (w/w)
- 5 to 10% fonio rejected via the rejection outlet.

➢ *Manufacture and field trialling of "hydrolift" prototype degritters.*

- *"Hydrolift 01" prototype degritter*

The good fonio degritting results obtained in the laboratory with the experimental model provided the design basis for a first prototype ("*hydrolift 01*" degritter). The equipment was built in Montpellier, and then sent to IMAF in Bamako to make the chassis and peripherals (hopper, collection vats, etc.) thereby completing the prototype assembly.

The prototype hydrolift was installed on the premises of Ucodal in Bamako for testing under actual conditions of use. The first trials conducted obtained a fonio throughput of approximately 100 kg/h, with a water flowrate of 60 l/min. The residual grit content measured in the fonio after hydrolift treatment was less than 200 ppm.

Figure 27. Hydrolift degritter and the degritting column at Ucodal, Bamako (© P. Thaunay, Cirad)

The operation of the degritter, incorporated into the production line at Ucodal, was monitored with the support of IER. The degritter was able to process 450 to 500 kg of fonio per day. In 2016, some modifications were made to the equipment (flowmeter, water filter, etc.) which improved its operation up to 500 to 800 kg per day.

Ucodal is highly satisfied with the equipment which provides a time saving in this degritting operation. Indeed, traditional manual degritting of 800 kg of fonio involves 18 women for a 9-hour working day, whereas degritting 800 kg of fonio with the hydrolift degritter involves only 10 women for a period of 8 hours. The labour freed up in this way could be employed in other, less arduous tasks. The company is considering investing in a second machine to increase its production.

- *"Hydrolift 02" prototype degritter*

The production tests of the *hydrolift 01* degritter were able to identify some possibilities for improvement, and led to the design of a second prototype ("*hydrolift 02*" degritter). This improved prototype was installed on the premises of Danaya Céréales in Bamako for testing under actual conditions of use. Analysis of the monitoring results demonstrates that the machine throughput could reach 130 kg/h, or even 150 kg/h, with a residual grit content considered satisfactory by the operators. Incorporated into the production line at Danaya Céréales, the *hydrolift 02* degritter was able to degrit 500 kg of fonio per day.

Figure 28. The Hydrolift 02 degritter at Danaya Céréales, Bamako (© P. Thaunay, Cirad)

- *Pilot lot of 2 "hydrolift" degritters*

The first 2 hydrolift prototype degritters, installed at 2 SMEs in Bamako (Mali), were able to achieve very good fonio degritting results under actual conditions of use. So it was decided to produce a pilot lot of 2 hydrolift degritters to equip 2 new fonio processing SMEs, in Burkina Faso and Senegal respectively.

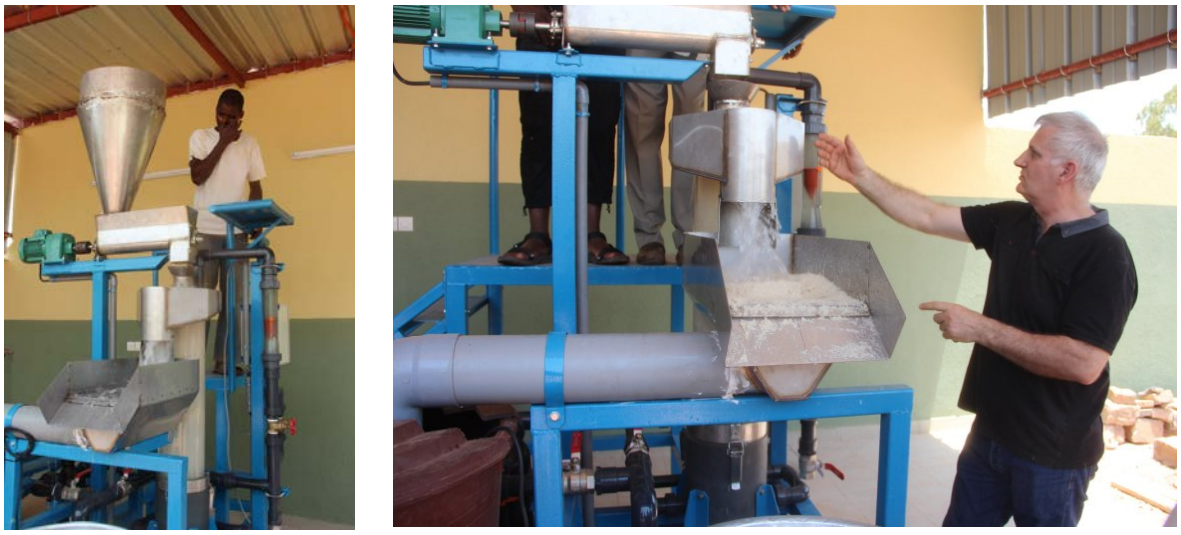


Figure 29. The hydrolift degritter in Bobo Dioulasso (© P. Thaunay, Cirad)

The pilot lot was made in Montpellier. With the support of the company Soldev (metal manufacturing) in Bobo Dioulasso (Burkina Faso) to make the chassis and peripherals, the first hydrolift was installed, in 2016, on the premises of the new fonio processing company (UTF), set up by its backer (F.X. Traoré from Bomborokuy) in Bobo Dioulasso. Incorporated into the production line, the equipment provides a throughput of 80 to 100 kg/h.

A second hydrolift was shipped to eastern Senegal. This equipment, designed and built in part by Cirad in Montpellier and by Soldev in Bobo Dioulasso, was sent to the Mamba Guirassy technical institute in Kédougou for final assembly, with the support of Cirad. In May 2016, the degritter was installed by Cirad at the "Koba Club" group in Kédougou.

Under actual conditions of use, the equipment is able to degrit fonio with a throughput of approximately 100 kg/h. Incorporated into the production line of the “Koba Club” group, the hydrolift degritter can process 200 kg of fonio per day, but should eventually be able to manage 500 kg per day.

Figure 30. Installation of the hydrolift degritter in Kédougou, eastern Senegal (© V. Bancal, Cirad)

Partial conclusion

The hydrolift degritter meets the specifications that the researchers had set, providing a throughput of around 100 kg/h and a residual grit content in the grain of less than 200 ppm. The private operators are also satisfied with the good performances observed under actual field conditions. So the mechanisation specialists have validated the equipment for degritting processed fonio. Local companies such as IMAF in Mali and SOLDEV in Burkina Faso were trained to carry out part of the equipment manufacture. Given its high capacity, this equipment is reserved for small companies likely to process at least fifty or so tonnes of fonio per year.

Activity 4. ***Adapting and validating dryers for processing SMEs***

✓ ***Construction, adaptation and validation of the CSec-T cross-flow dryer***

During the 2000s, Cirad designed and developed the CSec-T cross-flow dryer to improve the drying of granular solid foods such as rolled products (couscous, dégué, arraw, etc.) or processed grains (precooked fonio, germinated sorghum, etc.). In 2007, this equipment was tested by Cirad in Mali in collaboration with IER and the SME "Danaya Céréales" (Marouzé *et al.*, 2008). Under the Aval Fonio project, the aim was to scientifically validate the performances of this dryer and study the possibilities of local manufacture.

- *Principle of the CSec-T cross-flow dryer*

The cross-flow dryer comprises 3 compartments each containing 4 superimposed trays. It contains a hot air generator (gas burner) and an electric-motor driven fan. The dryer is made from plywood, and the hot air generator assembly is metallic.

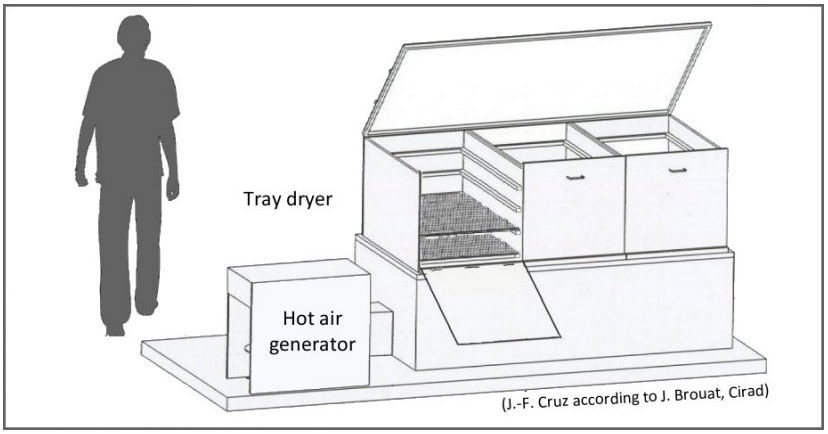


Figure 31. CSec-T dryer (© Cruz et *al*., 2011)

Each compartment is equipped with a door providing access to the various trays. The trays comprise a wooden frame and a galvanised metal mesh supported by stiffeners. Each tray is covered with a net or poplin type fabric. The hot air driven by the fan is introduced into the dryer via a duct, and then passes through the various trays from bottom to top, thereby drying the product.

The principle of the CSec-T cross-flow dryer is to create a counter-current movement between on the one hand the hot air flow which progresses from bottom to top in each compartment, and on the other hand the product which is gradually moved stepwise from top to bottom from tray position 4 to position 1. In continuous operation, the wet product is spread over a tray placed in the upper position 4 in the dryer. Once the cycle is complete, the dry product is removed from position 1.

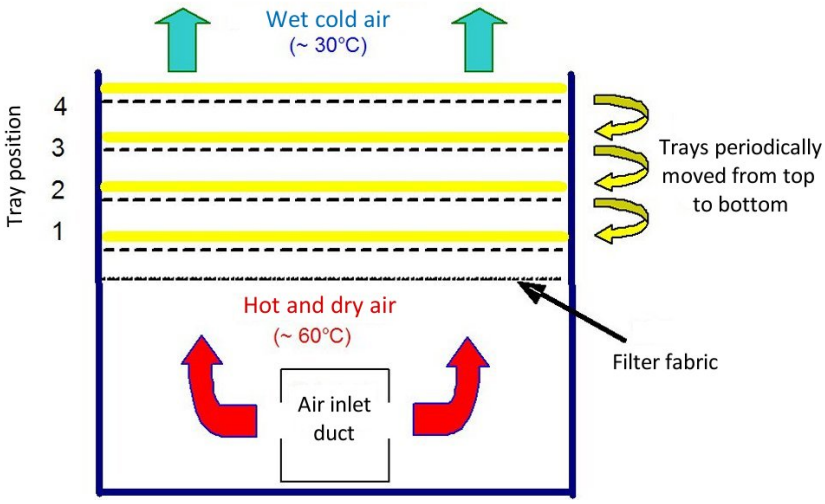


Figure 32. Schematic of the cross-flow dryer (© C. Marouzé, Cirad)

- *Construction, instrumentation and trialling of the CSec-T dryer*

A wooden cross-flow dryer was manufactured in Dakar as per the manufacture plans provided by Cirad, and with the support of the Mechanical Engineering Department of ESP (figure 33).

Figure 33. CSec-T dryer manufactured in Dakar (© ESP)

The CSec-T dryer, equipped with various sensors, test dried 90 kg of precooked fonio from 35 % to 10 %. Under the trial conditions (45 °C hot air), the CSec-T dryer was able to dry the precooked fonio with a throughput of 30 to 35 kg/h, adjusting the trays every 30 to 40 mins. With a butane gas consumption of 2.9 kg, the energy efficiency of the CSec-T dryer was approximately 45%. With a completely full dryer, we can anticipate an energy efficiency of more than 50 %, whereas conventionally used dryers in natural convection (Atesta dryer) have an energy efficiency of often less than 20 %. To improve the dryer's performances (reduce the drying time), it would seem necessary to increase the burner power (up to 8 kW) in order to achieve hot air inlet temperatures of 60 to 65°C.

- *Transfer of the CSec-T dryer to the field in eastern Senegal*

In light of the conclusive trials, the CSec-T cross-flow dryer was transferred to Salémata (eastern Senegal) for use by a group of 10 associations of women fonio processors.

Figure 34. Training operators to use the CSecT dryer in Salémata (© ESP-UCAD)

Two days' demonstration (drying approximately 150 kg of precooked fonio) were used to train the women how to use the dryer. The processors, with great enthusiasm and motivation, have continued to use the dryer and pass on the information gathered (quantities dried, gas consumption, etc.) to ESP-UCAD in Dakar.

- *Transfer of the CSec-T dryer to the field in Burkina Faso*

In Burkina Faso, two CSec-T cross-flow dryers were built in Bobo Dioulasso by SOLDEV, assisted by a dryer manufacturer (A. Souaré), with the support of a Cirad technician and under the aegis of the supervisors of WP4 "The innovation process in small fonio processing plants". Two training sessions on how to use CSec-T dryers were conducted in Bobo Dioulasso for fifteen or so fonio processors from western Burkina Faso and from Ouagadougou. They were held in March 2016, at IRSAT in Bobo Dioulasso, led by researchers and technicians from Cirad, IRSAT and ESP-UCAD. A facilitator responsible for supporting the women processors for the NGO "Afrique verte Burkina – Aprossa" and the two dryer manufacturers also took part in this training.

Figure 35. Training in how to use the CSecT dryers in Bobo Dioulasso, Burkina Faso (© T. Ferré, Cirad)

A CSec-T dryer user manual was drawn up to help train the operators:

Cruz J-F., Rivier M., Ferré T., Delpech A., Diallo A., Kebe C.M.F. 2016. CSec-T dryer User Manual. Aval Fonio project, deliverable no.15. Cirad. Montpellier. 7 p.

During the training session, 55 kg of precooked fonio was dried from 35 % to 10 % by way of an operating trial (figure 36).

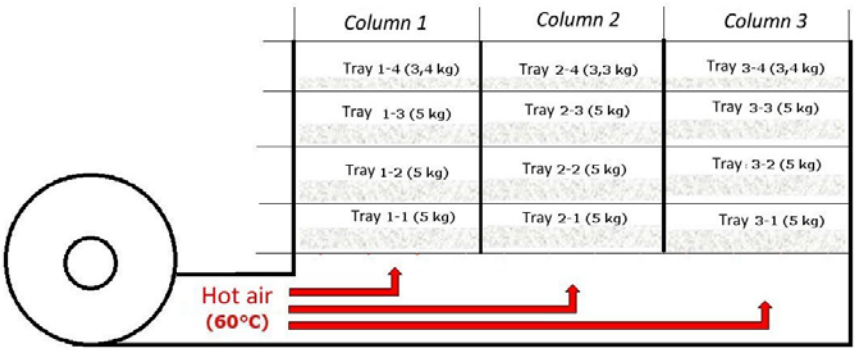


Figure 36. CSecT dryer load diagram (© J-F Cruz, Cirad)

Under the trial conditions (hot air at 60°C), the CSec-T dryer was able to dry the precooked fonio in 2.20 hrs, with a butane gas consumption of 1.5 kg and an energy efficiency of 59 %. This efficiency is better than the 45% observed during the trials in Senegal, since the hot air inlet temperature was maintained at 60 °C, whereas it was just 45°C in the Dakar trial. This efficiency of 59 %, excellent in itself, could be further improved by increasing the quantity of fonio to be dried, i.e. by adding wet trays when the bottom trays are dry and have been emptied.

After the demonstration trials, the two CSec-T dryers were installed on the premises of two fonio processing SMEs to be monitored under actual conditions of use. These two SMEs, “Tout Super” in Toussiana and EOBA in Ouagadougou, were selected because they have always closely collaborated with the researchers working to improve the fonio industry in West Africa.

Partial conclusion

The CSecT dryer meets the specifications that the researchers had set, by ensuring a load capacity of approximately 100 kg and a throughput of 30 to 35 kg/h for drying wet processed fonio (white or precooked) from 35% to 10%. Using a hot air inlet temperature of around 60 °C (burner power 8 kW), it was able to achieve an energy efficiency of around 60%, distinctly higher than the 20 % efficiency obtained with artisanal dryers based on natural convection (Atesta). The private operators which had the opportunity to use the CSec-T dryers were satisfied with the good performances observed under actual conditions of use. So the mechanisation specialists have validated this equipment for drying processed fonio (whitened and/or precooked). A local company, SOLDEV in Burkina Faso, has been trained to manufacture the equipment.

✓ ***Design, adaptation and validation of the CSec-S "greenhouse" dryer***

- *Principle of the CSec-S "greenhouse" dryer*

During the 2000s, a *CSec-S "greenhouse"* dryer was designed by Cirad and tested in Mali (figure 37). Under the Aval Fonio project, the aim was to scientifically validate the performances of this sort of dryer and investigate the possibilities for local development.

Figure 37. CSec-S "greenhouse" dryer installed by Cirad in Mali in 2006 (© J-F Cruz, Cirad)

The greenhouse dryer represents an alternative to direct solar drying. The product is dried by direct exposure of the product to solar radiation and via the greenhouse effect (higher temperature inside the greenhouse than outside). The objective is to carry out drying at a relatively low temperature using solar radiation as a heat source.

The greenhouse dryer was designed:

- on the one hand, to protect the products to be dried (fonio or other products) from the weather, birds and airborne dust,
- on the other hand, reduce handling of the product. By contrast to natural sun drying, there is no need to bring in the products when the rains arrive or in the evening if the products have been put out to dry during the day.

- *Construction and instrumentation of an experimental CSec-S dryer in Senegal*

Based on the specifications drawn up in 2013 with Cirad, two CSec-S "greenhouse" dryers were ordered from FilClair (Marseille, France) in 2014. This equipment was delivered to Senegal and one of the CSec-S "greenhouse" dryers was installed on the ESP-UCAD site in Dakar by the Mechanical Engineering department in 2014 (figure 38).

The greenhouse dryer comprises an agricultural greenhouse with a surface area of approximately 90 m² (14 x 6.4 m) and a volume of 200 m^3 (figure 39).

Figure 38. View of the CSec-S dryer (© T. Ferré, Cirad)

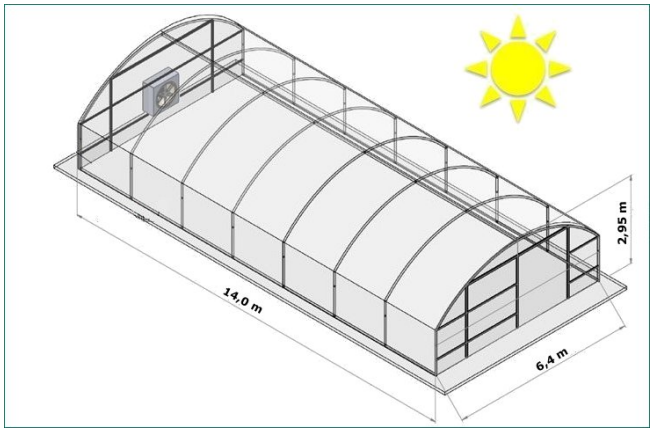


Figure 39. Diagram of the "greenhouse" dryer (© ESP)

The CSec-S “greenhouse” dryer is equipped with 8 rectangular trays suspended from the greenhouse frame arches. The trays are made from wood with a wire netting base covered with a net or poplin type fabric to hold the fonio spread in a thin layer (figure 40). The dimensions of the trays are 2.5 m x 1.5 m (with separation into 4 zones representing a useful surface area of 3.5 m²).

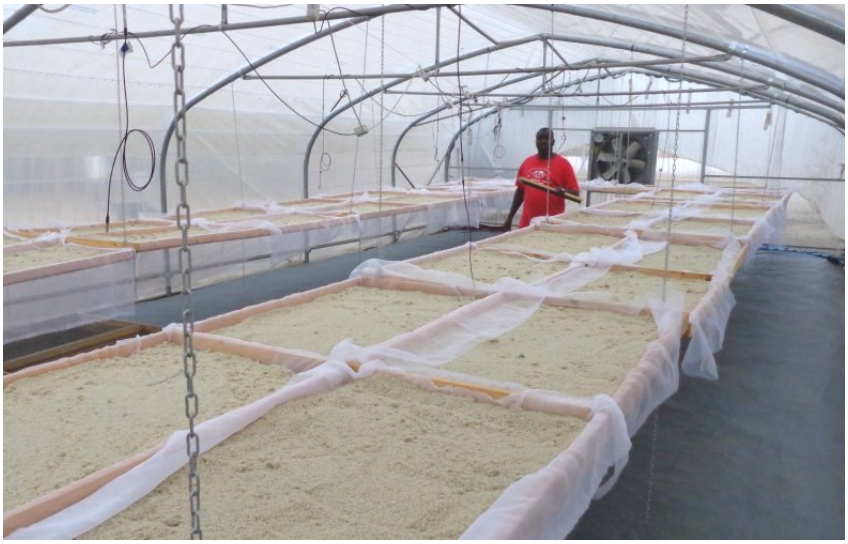


Figure 40. Thin layer of fonio on the drying trays (© M. Rivier, Cirad)

The greenhouse dryer is equipped with the following instrumentation:

- thirteen thermometers-humidity sensors distributed throughout the greenhouse,
- a pyranometer for measuring solar radiation, mounted on a post outside the greenhouse,
- an acquisition centre for the data read by the sensors and pyranometer.

During trials conducted in Dakar, the solar radiation on the greenhouse (expressed in W/m²) could be read on the pyranometer. The curve in figure 41 shows that the solar radiation is most efficient (> 600 W/m²) between 10:00 and 16:00, with a maximum of close to 1000 W/m² at around 13:00.

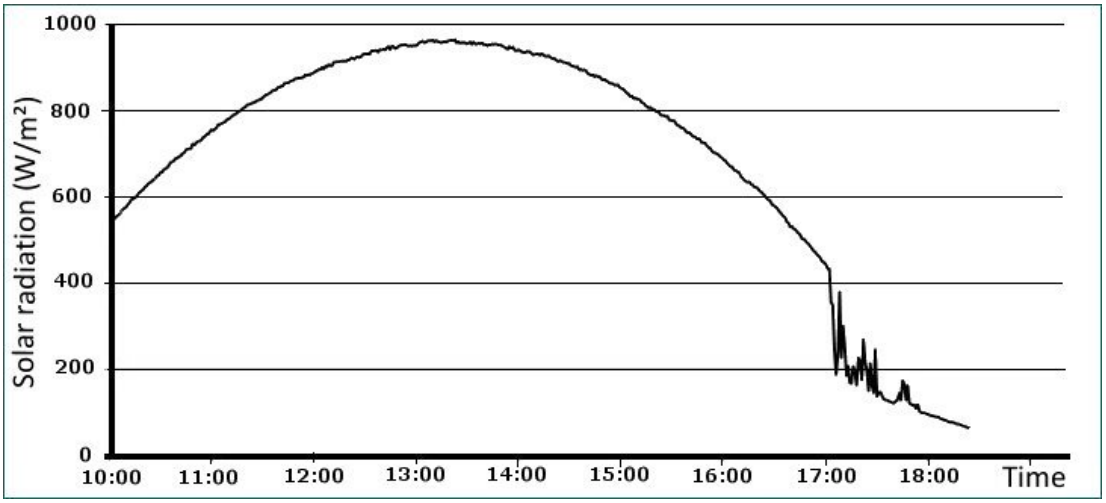


Figure 41. Solar radiation on the greenhouse over the course of a day (© M. Rivier, Cirad)

With an outside temperature of 30 °C, the temperature in the greenhouse may reach 55 to 60 °C. This temperature can be lowered by activating the extractor to enable the operators, if need be, to load or empty the dryer under milder temperature conditions.

- *Experimental CSec-S dryer validation trials in Senegal*

After some preliminary validation trials on the experimental CSec-S dryer conducted at ESP-UCAD with the support of Cirad, a full-scale drying trial was conducted during an Aval Fonio workshop held in Dakar in June 2015. It involved drying 315 kg of wet precooked fonio (in principle 35 %) distributed in a thin layer over 10 trays (or 35 m²), as illustrated in figure 42.

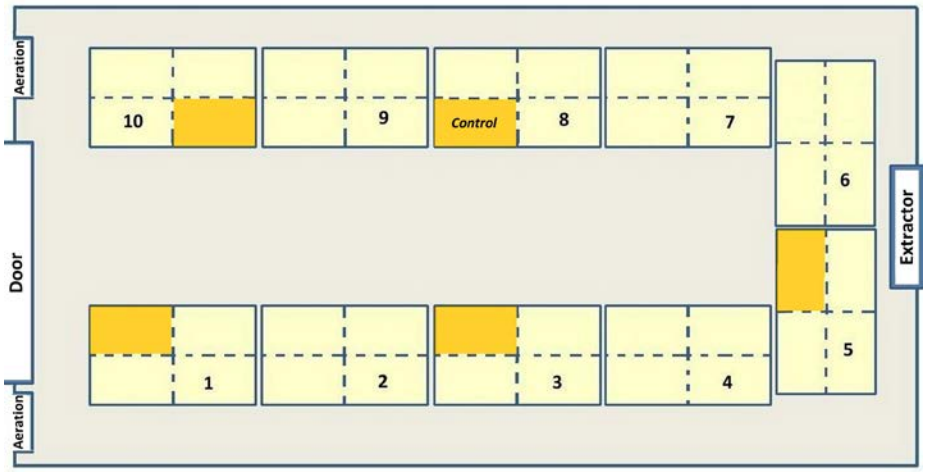


Figure 42. Layout diagram of the drying trays in the CSec-S dryer (© M. Rivier, Cirad)

At the end of the test, we obtained 210 kg of dry fonio after a greenhouse retention time of more than 20 h (with approximately 9 h of actual sun exposure).

Figure 43. Fonio greenhouse drying trial in Dakar (© J-F Cruz, Cirad)

- *Transfer of the CSec-S dryer to the field in Senegal*

A CSec-S "greenhouse" dryer was transferred to the Koba Club group in Kédougou, eastern Senegal, at the end of 2015. Initial operating tests were able to dry approximately 250 kg of precooked fonio.

The Koba Club group then continued to use the dryer, drying 150 to 250 kg of fonio per day. It was noted that the Koba Club group loaded the dryer with wet fonio in the evening after 18:00. This practice is not ideal, since the dryer is in this way filled with a large mass of wet product at a time of day when solar radiation is negligible. Thereafter a period of fifteen hours (night and early morning) will pass, during which the temperature in the greenhouse drops, and may cause high risks of condensation (and possibly fermentation) before the solar radiation regains its efficiency.

Figure 44. The CSec-S greenhouse dryer at the *Koba Club* group in Kédougou, Senegal (© A. Diallo, ESP/UCAD)

Partial conclusion

The 90 m² *CSec-S* greenhouse dryer, equipped with 10 trays or more, meets the specifications that the researchers had set, ensuring a load capacity of approximately 300 to 350 kg to dry wet processed fonio (white or precooked) from 35% to 10% in 24 h. The private operators which had the opportunity to use the *CSec-S* dryers are satisfied with the good performances observed under actual field conditions. To ensure more rational use of the greenhouse dryer, we must recommend loading the dryer in the late morning, in order to fully harness the solar radiation to ensure efficient drying and rapid stabilisation of the fonio. So the mechanisation specialists have validated this equipment for drying processed fonio (whitened and/or precooked). Distribution of this type of dryer should be promoted among agribusiness processing units, since it is versatile and should be usable on various types of agricultural products. The target SMEs must however have a sufficiently large and clear space to enable its installation.

Note: Installing a "greenhouse" dryer in the field in Guinea.

To enable certain operators in Guinea to benefit from the results of the Aval Fonio project in terms of drying, a small greenhouse dryer was installed in the rural community of Pilimini (Koubia prefecture). In this village in Fouta Djallon, a women's group wanted to develop its fonio processing activity to boost the value of this cereal by producing precooked fonio (a processed form of fonio which is rare in Guinea). The group is supported by the Franco-Guinean NGO ADESAG, which works for the development of socially responsible enterprise in Guinea, and which has already equipped the group with a GMBF huller-whitener.

Initially, as the quantities processed by the women processors were still relatively low (a few tens of kg), it was agreed that the Filclair brand greenhouse dryer was oversized, and that a dryer of only around 20 m² should be installed.

A Tonneau brand greenhouse ("5ème saison" line) was chosen, with the following characteristics: length: 4.5 m, width: 5 m, height: 2.37m. The greenhouse comprises a galvanised steel frame with a transparent reinforced PVC covering. Given its small size, the greenhouse is not equipped with an air extractor, but simply with a door on each of the gables, to facilitate the air current to enable natural aeration.

In Pilimini, the greenhouse was installed on a slab laid by the beneficiaries.

Figure 45. Greenhouse dryer (Tonneau brand) in Pilimini, Guinea (© H. Baldé, Adesag)

2.2.4. WP4: The innovation process in small fonio processing plants

WP4 is aimed at firstly generating knowledge about the innovation process involving small fonio processing companies. It is also aimed at developing a co-design system of fonio processing and stabilisation technologies (washing, degritting and drying), bringing in alongside the WP3 researchers the field players (equipment manufacturers, potential users, support structures, etc.) who are also stakeholders in the innovation process.

Activity 5.1. *Identifying the processing innovation system players*

In Burkina Faso, two studies were conducted on equipment manufacturers in the cities of Ouagadougou and Bobo Dioulasso. This work was used to characterise these players, but also to identify potential partners capable of contributing to the development and dissemination of fonio processing equipment. The selection was made mainly on the basis of five criteria: the nature and complexity of producing the equipment already manufactured, qualification of the company manager and their personnel, the equipment and machine tools available in the production unit, experience of partnerships and desire to collaborate with research.

Hence the researchers made an initial selection of four companies: NTELFAC (formerly SGGI), SRC, REMICO and Agri-Equipement. At the project annual meeting held in Burkina Faso in January 2015, a meeting was organised with the companies REMICO and Agri-Equipement, which are IRSAT partners in manufacturing GMBF hullers and screening cleaners.

Figure 46. Visit to the company Agri-Equipement in Ouagadougou (© J-F Cruz, Cirad)

In Mali, a survey of the fonio processing units in Bamako was conducted district by district. The results reveal the existence of at least 71 fonio processing companies in Bamako (figure 47). This is an activity practically exclusively carried out by women, and the few men in these companies are assigned to operating equipment (hullers, mills and dryers). In addition to their fonio production, these companies generally manufacture a wide range of cereal products or condiments.

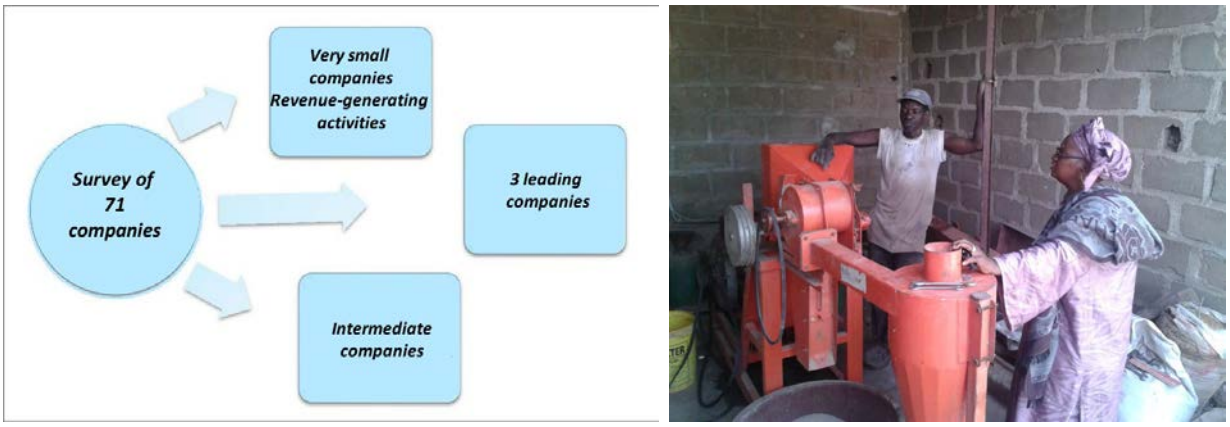


Figure 47. Fonio processing units in Bamako (© T. Ferré, Cirad)

More than a thousand people are directly employed, on a temporary or permanent basis, by these processing units. There is a dual trend in this sector of activity: both a proliferation in the number of companies, with more than 80% established in the 2000s, but also by the expansion of some of them.

We were able to identify 3 processing companies as the sector leaders: UCODAL, Danaya Céréales and Dado Production, which sell their production on both the national and export markets, in Europe and North America. There is a very high investment level in the business. They use premises dedicated entirely to processing products, and have introduced a host of equipment in their production process (rotary screens, GMBF hullers, gas dryers, mills, etc.).

Activity 5.2. ***Studying the relations between the components of the innovation system***

The adopted starting point of the analysis of the components of the innovation system and their interrelations was the observations and surveys, as well as technical changes (specific equipment) which have occurred in fonio processing techniques. The particular focus was on the *GMBF huller*, which was designed and then introduced and disseminated in 2002 under the first fonio project.

✓ ***Innovation impact study of the "GMBF huller" in Burkina Faso and Mali***

Impact assessment approach

The analysis was based on the ImpresS methodology developed by Cirad.

The impact pathway can be represented by the diagram below:

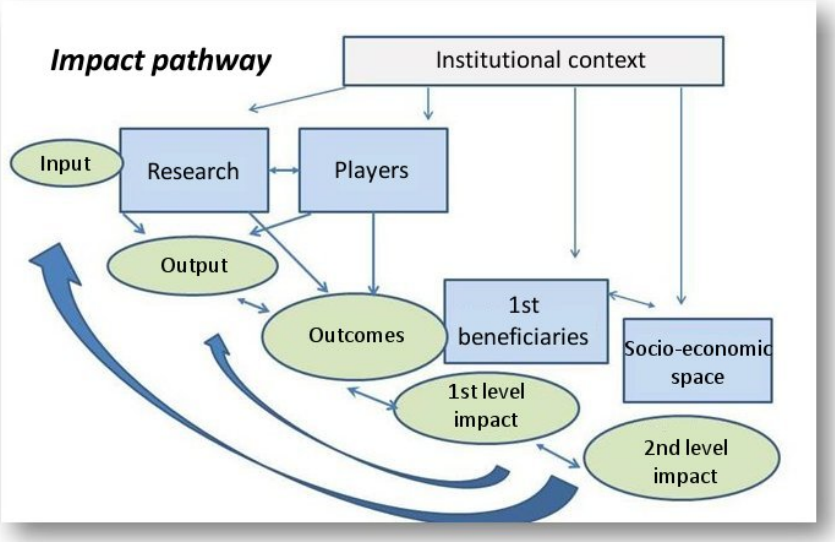


Figure 48. Impact pathway diagram (© Cirad Impress)

Impact assessment study

The study was conducted by Cirad with the collaboration of IRSAT and the support of an ISTOM intern assigned first to Cirad, and then to the field in Burkina Faso during the first half of 2015. For the field surveys in Burkina Faso, Cirad and IRSAT requested the collaboration of the NGO "Afrique Verte" (Aprossa). In Mali, they collaborated with the NGO "Afrique Verte" (Amassa) and IER (Ms. F. Guindo).

To kick off the impact assessment study, a Cirad & IRSAT joint mission was conducted in western Burkina Faso (Boucle du Mouhoun) in May 2015. This mission provided the opportunity to meet a number of industry operators:

- Collective interviews with 2 producers' groups from Bomborokuy: "Varossé" (23 producers) and "Zoumé" (14 producers)
- Collective interviews with 3 women processors' groups from Bomborokuy: "Passé" association (55 women), "Brayorona" association (34 women) and the Benkadi group.
- Individual interviews with companies which have installed a GMBF huller-whitener / Identifying the dynamics in progress / Evolution of business (in Bomborokuy, Nouna and Djibasso)
- Meeting with Mr. François Ouedraogo (State Contract/35 IMAF hullers for Burkina).
- Meeting with "Afrique Verte" (Aprossa) and IRD project (International Relief & Development.)

Main information collected in Burkina Faso

For the producers and women processors, the main changes observed over recent years are:

• Change in the status of fonio: from a lean-season cereal to a commercial product,
• More than 2/3 of production goes onto the market,
• General increase in total surface areas sown with fonio / and per producer,
• Increase in fonio sale price,
• Dynamic in progress thanks to: threshers and hullers available on a contract basis,
• More than half of production is produced by hullers,
• Service price: 1000 FCFA / tine (approx. 15 kg) i.e. 67 FCFA/kg (or €0.1/kg).

The main constraints remain the lack of threshers and hullers.

A company from Bomborokuy (F.X. Traoré), equipped with 3 GMBF hullers and 2 threshers ("Bamba", manufactured in Mali), has been operating in production and contracting since 2010. In 2014-2015 it handled 50 tonnes of whitened fonio. It sells mainly to Mali, though it is faced with strong competition on this market.

Figure 49. GMBF hullers in Bomborokuy (© T. Ferré, Cirad)

In 2015, the company set up in Bobo Dioulasso to form a fonio processing unit (UTF) covering the process all the way to the finished and packaged product. It welcomed the installation of the hydrolift degritter (see § 2.2.3), and invested in a CSec-T cross-flow dryer (Aval Fonio project equipment).

A company from Nouna (Gaia Bio Solidaire) has produced parboiled semi-wholegrain organic fonio for export since the 2000s. The company is certified by Ecocert and supported by the NGO "Orange Bleue Afrique". In 2014-2015, it produced 30 tonnes, 26 of which were exported since wholegrain fonio is still difficult to sell on the local or regional market. It supervises 9 groups representing nearly 400 organic producers, and purchases the raw material at 175 FCFA/kg (instead of 150 FCFA/kg which is the price usually charged). The 30 tonnes over the 2014-2015 campaign was purchased from 50 producers.

The company is equipped with two GMBF hullers and a rotary screen. The company produces parboiled semi-wholegrain fonio. The processing scheme comprises the following operations: cleaning (screening), washing-degritting, parboiling, drying and then hulling (with partial whitening). The unit can process 560 kg of fonio per day.

Finally, a company from Djibasso (P. Koeta) is equipped with an engine-driven GMBF huller and a rotary screen on a contracting basis.

Figure 50. GMBF huller at Gaia, Nouna (© T. Ferré, Cirad)

Main findings in Burkina Faso

The fonio hullers currently installed by the companies are GMBF hullers manufactured by IMAF in Mali. Although this huller was developed in the early 2000s, there are still no manufacturers able to provide it in Burkina Faso.

At the project annual meeting in Ouagadougou of January 2015, the researchers had the opportunity to meet the company REMICO from Ouagadougou, which was manufacturing some machines, but other manufacturers were also identified, as shown by table 4 below.

Table 4. Some equipment manufacturers identified in Burkina Faso

Company	Representative	Associated system	Location	Research support
ACEMG	Hermann Ouedraogo	US IRD project	Bobo Dioulasso	Identified by IRSAT for training in building a variety of fonio and sesame equipment
Ets Godijo et frères	Omar Godjio	US IRD project	Banfora	
AgriEquipements	Alassane Ganou	US IRD project	Ouagadougou	
Remico	Yves Zongo	US IRD project	Ouagadougou	
Yétéli Constructions	Jean Kamaté	US IRD project	Nouna	
AMB	Joseph Pogogné	IRSAT subcontracting	Ouagadougou	Parts manufacturing
STAB	Sory Sanogo	CFC fonio project	Bobo Dioulasso	CFC fonio project (whitener cone, but abandoned)
AGCM	Karim Guira	IRSAT subcontracting	Bobo Dioulasso	Produced jigs based on GMBF from Ms. Traoré
SOAF	Mamadi Camara	Independent	Bobo Dioulasso	Says that the market is insufficient

In Burkina Faso, the lack of clearly accredited fonio equipment manufacturers is still forcing processing companies to procure machinery from Mali (IMAF); which may cause various difficulties with equipment maintenance.

The IRD project [International Relief & Development (2013-2015)] was conducted in the fonio post-harvest segment in collaboration with IRSAT and “Afrique Verte”. It was planned to train five equipment manufacturers in manufacturing the GMBF huller (see table no.4). This may seem excessive, since it would be more realistic to select at most 2 equipment manufacturers (1 in Ouagadougou and 1 in the Bobo Dioulasso region), which could work in direct collaboration with IMAF in Bamako.

Main information collected in Mali

In Mali, the system of assessing the impacts of the fonio huller innovation was based on an identical approach. The Malian Association for Food Security and Sovereignty (AMASSA - Afrique Verte Mali) contributed actively to implementing the impact assessment approach proposed by Cirad. In particular it was able to hold the participatory workshops with the fonio industry players, and conduct certain field surveys with the support of Ms. Fanta Guindo (IER). The study made it possible to develop an impact pathway which helps identify the contribution of research to the process.

The impacts were characterised by descriptors which are meaningful for the players. These descriptors were produced during individual or group interviews, first of all during the account of the innovation, and then at a participatory workshop held in July 2015 in Bamako with the fonio industry players. These descriptors were then converted into a limited number of indicators, which may be quantifiable or assessed qualitatively, and which indicate an evolution between a reference situation and the execution period of the study. Finally, the results of the analysis were validated at a final workshop with the players, which was held in June 2016 in Bamako.

Main findings in Mali

The main findings emerging from this analysis in terms of the companies are as follows:

- The “*GMBF fonio huller*” innovation had a considerable impact on the equipment manufacturer IMAF and on the women processors who participated in its development. IMAF sold nearly 112 fonio hullers. The women processors saw a big increase in production volumes. In the space of 15 years, the annual production of the 3 main Malian companies went from a few tonnes to more than one hundred tonnes, creating forty or so jobs. In late 2015, *Danaya Céréales* opened a new production unit (figure 51) in the industrial zone of Dialakorobougou, situated on the outskirts of Bamako. Its objective is to process 4 tonnes of fonio per day in 2018, to better satisfy the growing demands on the domestic and export markets.

Figure 51. Danaya Céréales in Dialakorobougou (© P. Thaunay, Cirad)

- The women processors who are not equipped with a GMBF huller do however have access to this equipment, thanks to the emergence of primary processing companies which sell hulled and whitened fonio, or thanks to service providers. This is the case in Bamako, but also in the provinces. Thus in the region of Ségou, the company UTC based in San, which started operating with fonio in 2009, now processes nearly 1200 tonnes of fonio per year. It owns 6 hullers and employs 22 permanent and 30 temporary staff.
- In Bamako, 80 % of fonio processing companies were created over the period 2000-2015.

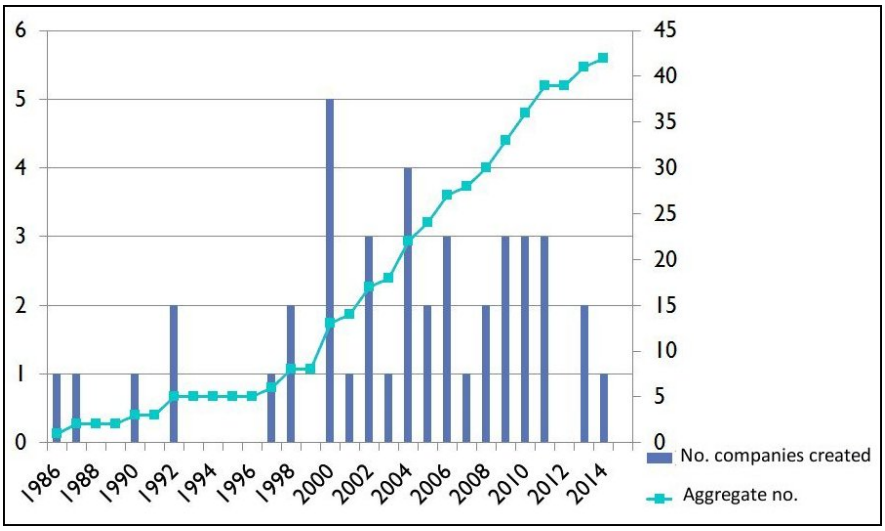


Figure 52. Evolution of creation of fonio processing companies in Bamako (Mali)

- In rural zones, the installation of hulling service workshops has helped maintain or even expand fonio cultivation**.** Thus, 80% of producers surveyed in the villages equipped with or close to a huller state that their fonio cultivated surface areas have increased since the installation of the machine. All the producers surveyed consider that there has been an increase in the number of fonio producers in their village since the arrival of the huller.
- All producers marketing their fonio consider that their revenue has increased thanks to fonio sales: 50% rate this increase as very large, 40 % as medium, and 10% as minor.
- All fonio producers surveyed state that their dietary situation has improved thanks to the maintenance or expansion of fonio cultivation. The producers say that they retain all or some of their fonio harvest for family consumption. Since the fonio harvest comes before that of the other cereals, it therefore provides food during the lean season. The majority of producers surveyed also underline the usefulness of fonio in enabling them to diversify their diet and offering the option of preparing various types of dishes.
- The mechanisation of hulling is contributing to improving the living conditions of rural households. In the villages surveyed, all the women emphasise that the huller has released them from a task which they deem highly arduous. Women and men are unanimous in saying that the huller has eased the workload, saving fonio from a steady decline. They all say that mechanical hulling has helped reduce family tensions.

✓ ***Lessons on the innovation approach***

Besides the results in terms of impacts, the case study relating to GMBF huller has helped enrich the debate on the management of innovation projects and on the conditions and mechanisms promoting the appropriation of research results by agribusiness companies. The study contributes to answering the questions raised on: how to improve the technological innovation approaches implemented by the researchers? How to support SME innovation in agribusiness?

Certain conditions were essential for the equipment manufacturers and women processors to appropriate the research results. The operating methods which seem crucial in the typical case of the GMBF huller are: joint design via a multi-player system, the strong interactions between researchers and key system players, a strong desire for innovation among the women processors - the future users of the huller - involvement by research which extended beyond the project's lifetime, and involvement by NGOs in disseminating the innovation on a wider scale.

Activity 5.3. *Supporting innovation processes*

Under this activity, the WP4 team supported the activities carried out by WP3: on the one hand "*Manufacture and field trialling of a hydrolift prototype degritter*" and on the other hand "*Transfer of the CSec-T dryer to the field in Burkina Faso*".

The system set up in Bobo Dioulasso, an innovation platform which was able to obtain certain results (presented in paragraph 2.2.3), was based on putting together a set of players (equipment manufacturer SOLDEV, the number one fonio processing company in the sector, women fonio processors from the network RTCF, the NGO Aprossa-Afrique Verte and researchers from IRSAT and Cirad).

This set-up made it possible to bring together various players who for the most part had never met (equipment manufacturers and women fonio processors). Another aim was to generate interactions between researchers and key players capable of make a big contribution to disseminating innovations through training: training equipment manufacturers in manufacturing the CSec-T dryer, and training women processors how to use the dryer.

The manufacture of two *CSec-T* dryers in the workshop of SOLDEV meant that the equipment could be adapted to local manufacturing conditions, and the manufacturing cost evaluated. The training sessions bringing together manufacturers, women processors, researchers and NGOs provided an understanding of the appropriation conditions. In addition to the 2 dryers manufactured with Aval Fonio project funding, SOLDEV manufactured and sold 3 other dryers for women processors from Bobo Dioulasso and Banfora.

Partial conclusion

The innovation dissemination support system set up in Bobo Dioulasso (Burkina Faso) has only been in place since the end of 2015. Although recent, it has already given some encouraging results, and needs support.

This type of system is largely inspired by the innovation platform concept, as well as the findings of the *GMBF fonio huller* innovation case study. Through this approach, the objective is to answer the question of how to promote access and actual use of agribusiness innovations by SMEs for the purpose of boosting the sector's productivity, contributing to economic growth and thereby contributing to food security and poverty reduction.

There are already a number of innovation platform trials in Africa. Most are focused on agricultural activities, and put the producers at the core of the system. Yet few innovation platform trials are focused on technological innovation in agribusiness. This sort of system, networking the various players capable of playing a role in the design and adaptation of the innovations, seems promising in the field of agribusiness technological innovations.

The challenges for research are to:

- Design new technical references
- Build up the knowledge of the SMEs: women processors and equipment manufacturers
- Renew interactions between the local players
- Support the innovation processes.

2.2.5. WP5: Facilitation, coordination and communication

The Aval Fonio project (AURG/161/2012) signed at the African Union meeting in Addis Ababa on 17 December 2012 for a term of 36 months was extended by 6 months until 16 June 2016.

Activity 6.1: *Creating a website to inform the players*

The project website, which went online in September 2013, was regularly updated throughout the project. It comprises a French version (http://aval-fonio.cirad.fr/) and an English version (http://aval-fonio.cirad.fr/en).

Activity 6.2: *Organising a seminar, inviting other producer countries*

This activity was replaced by the final meeting, which was held in Montpellier (France) in June 2016.

Activity 6.3: *Publication of results in the form of articles and a CD-ROM*

The partners were encouraged during the project to publish outreach articles, short "journalistic" pieces, posters, etc. to raise awareness of fonio in general and/or of the results obtained under the Aval Fonio project in particular.

Various posters were produced for various events, to illustrate the research conducted under the Aval Fonio project and to exhibit the results obtained.

An article entitled "*La mécanisation du décorticage du fonio a réduit la pénibilité et contribué à la durabilité de la filière*" ["Mechanisation of fonio hulling has reduced workload and contributed to the sustainability of the industry"] was drawn up for the book "*Développement durable et filières tropicales*" ["Sustainable development and tropical industries"] published in 2016 by Editions QUAE.

An Aval Fonio project presentation brochure was produced for the African Union. It is available in French and English versions.

An article "*Fonio et Quinoa, deux nouvelles graines à la conquête des marchés*" ["Fonio and Quinoa, two new grains on the lookout for markets"] is currently being drafted for publication in the review "*Agronomie, environnement et sociétés*" of the French association for agronomy.

The book "Fonio, an African cereal" was published in July 20216 (Editions Cirad, IRAG).

Reference: *Cruz J-F, Béavogui F., Dramé D., Diallo T.A. 2016. Fonio, an African cereal. Editions Cirad/IRAG, Montpellier, France, 153 p.*

This book is the updated English version of the book "*Le fonio, une céréale africaine*" published in 2011 by Editions QUAE. Dedicated to the fonio, this book addresses all aspects of this small cereal, from cultivation to processing, and even provides some recipes. It provides a summary of around twenty years' research conducted in West Africa, under international projects.

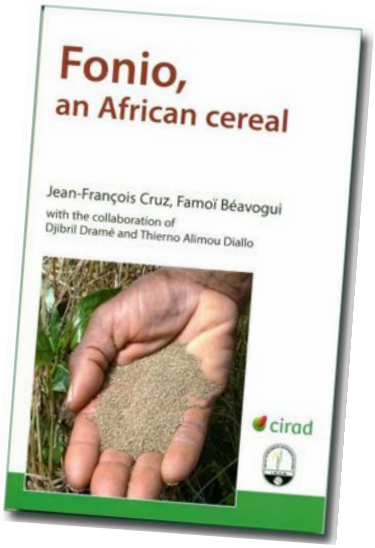


Figure 53. "Fonio, an African cereal" (© Cruz, Cirad)

An Aval Fonio CD-ROM is under preparation to bring together all the project deliverables.

Finally, a short documentary film about fonio has achieved:

Morlet N., with the collaboration of Cruz J.-F., Fonio, 2016.

Activity 7.1: *Organising and facilitating specific workshops and the annual meetings*

In the course of the project, the coordinators organised various meetings and workshops which were the main milestones of the project (table 5), namely: kick-off meeting in Dakar (Senegal), four researchers' workshops and three annual meetings of the Steering Committee in various countries, and the final meeting in Montpellier (France).

Table 5. Calendar of meetings and workshops held

Meetings or workshops	Country	Country	Month	Duration (d)
Kick-off meeting	Senegal	Steering committee + partners and researchers	15-16 April 2013	2
WP1 to WP4 workshop	Senegal	Researchers and concerned local partners	17-19April 2013	3
WP3 & WP4 workshop	Burkina Faso	Researchers and concerned local partners	19-21 November 2013	3
Annual meeting	France	Steering committee + concerned local researchers	7 - 11 April 2014	4
WP1 to WP4 workshop	Mali	Researchers and concerned local partners	9 – 13 June 2014	3
Annual meeting	Burkina Faso	Steering committee and concerned local partners	19-23 January 2015	4
WP1 to WP4 workshop	Senegal	Researchers and concerned local partners	8 – 12 June 2015	3
Annual meeting	Senegal	Steering committee and concerned local partners	1 – 5 February 2016	4
Final meeting	France	Steering committee + researchers	6 – 11 June 2016	4

✓ ***Kick-off meeting and workshop in Senegal***

Under the aegis of Cirad and the Polytechnic Higher Institute of Cheikh Anta Diop University (ESP/UCAD), the kick-off meeting and the first workshop on the work packages were held in Dakar (Senegal) from 15 to 19 April 2013. They brought together thirty or so participants, including researchers and administrative agents from Burkina Faso, Burundi, France, Guinea, Mali and Senegal, as well as industry players, mainly women processors, and research partners.

Figure 54. Aval Fonio project kick-off meeting in Dakar (© Cirad)

✓ ***Work packages workshop in Burkina Faso***

The work packages workshop was held from 18 to 22 November 2013 at the headquarters of the Cirad Regional Directorate in Ouagadougou. It brought together ten or so researchers and technicians from the Aval Fonio project, from Burkina Faso, France, Mali and Senegal. It provided an opportunity to meet women fonio processors in Ouagadougou and visit the laboratories of IRSAT, an Aval Fonio project partner in Burkina Faso.

✓ ***2014 annual meeting in France***

The first annual meeting of the Aval Fonio project was arranged by Cirad in Montpellier from 7 to 11 April 2014. It brought together around fifteen project participants, partners and associates, from Burkina Faso, Burundi, Guinea, Mali, Senegal and France. It helped analyse the state of progress of the activities of the various work packages and schedule the activities for the second year. It also provided an opportunity to visit certain laboratories and technical facilities of Cirad's "*Maison de la Technologie*" in Montpellier.

- ✓ ***Work packages workshop in Mali***

A work packages workshop was arranged by Cirad and IER in Bamako from 9 to 13 June 2014. The workshop brought together ten or so researchers from Burkina Faso, France, Guinea, Mali and Senegal. It provided the opportunity to visit the laboratories of IER/LTA, an Aval Fonio project partner in Mali, and meet various fonio industry private operators in Bamako, such as the processing units Ucodal, Dado production and Danaya céréales, and the equipment manufacturers IMAF and SIPS.

- ✓ ***2015 annual meeting in Burkina Faso***

In 2015, the Aval Fonio project annual meeting was held in Ouagadougou (Burkina Faso) from 19 to 23 January 2015. Organised jointly by Cirad and IRSAT, the annual meeting brought together all the project partners (Cirad, Irsat, IER, ESP-Ucad, CNTA), with the exception of IRAG from Guinea, which was unable to get to Burkina Faso. It provided the opportunity to visit fonio processing equipment manufacturers (Remico and Agri-équipement) in Ouagadougou.

- ✓ ***Work packages workshop in Senegal***

A work packages workshop was held in Dakar (Senegal) from 8 to 12 June 2015. The meeting brought together around twenty participants from Burkina Faso, France, Guinea, Mali and Senegal. The discussions reviewed the results of the research conducted in mechanisation of the fonio post-harvest segment. The workshop also provided the opportunity to conduct a drying trial on 350 kg of precooked fonio in the greenhouse dryer (CSec-S) designed by Cirad and tested at ESP-UCAD.

- ✓ ***2016 annual meeting in Senegal***

The third Aval Fonio project annual meeting was held in Dakar (Senegal) from 1 to 5 February 2016. Organised by Cirad and ESP-UCAD, the meeting concerned all the project partners and brought together a dozen participants (Cirad, ESP-Ucad, IER, IRAG and IRSAT. The object of the annual meeting was to analyse the results of the various activities carried out in 2015, and schedule the activities as far as the project closure. It also provided an opportunity to address the administrative and financial aspects of the project and to decide on a final meeting in Montpellier (France).

- ✓ ***Final meeting in France***

The Aval Fonio project final meeting was arranged by Cirad in Montpellier (*Maison de la Technologie*) from 6 to 10 June 2016, bringing together fifteen or so participants representing the various project partners. The final meeting drew up a detailed report of the numerous activities carried out under the Aval Fonio project, especially:

- Analysis of fonio production and post-harvest systems,
- Mechanisation of fonio post-harvest techniques (threshers and cleaners),
- Improving processing and stabilisation techniques (degritters and dryers),
- Innovation process in small processing plants.

The meeting also provided an opportunity to introduce the Southern partners to the various technical facilities of Cirad's Agri-food Platform.

From left to right: 2nd row: T. Ferré (Cirad), Ms. F. Boré Guindo (IER, Mali), J-F Cruz (Cirad), Ms. V. Bancal (Cirad), A. Diallo (ESP, Senegal), S. Camara (IRAG, Guinea), P. Thaunay (Cirad), I. Medah (IRSAT, Burkina Faso)

1st row seated: C.M.F. Kébé (ESP, Senegal), A. Delpech (Cirad), T. Goli (Cirad), A. Anne (ESP, Senegal)

Figure 55. Participants in the Aval Fonio project final meeting, Montpellier (© A. Servent, Cirad)

Activity 7.2: *Training the partners*

In 2013, a training session entitled "Equipment design methods" was conducted in Senegal by Cirad (P. Thaunay), at the request of the partner ESP-UCAD.

In 2016, a training session on how to use the CSec-T dryers was conducted in Bobo Dioulasso for fifteen or so fonio processors from western Burkina Faso and Ouagadougou. It was arranged at IRSAT in Bobo Dioulasso, and conducted by the researchers and technicians from Cirad, IRSAT, ESP-UCAD and in collaboration with the NGO Afrique verte Burkina - Aprossa.

During the project and the validation of the various equipment (dryers, degritters, etc.), Cirad and its partners were able to train the equipment manufacturers and fonio processors in the manufacture and use of the equipment.

2.3. Modified activities

2.3.1. WP1: Analysis of production and post-harvest systems

There were no major delays in the execution of the WP1 activities.

2.3.2. WP2: Mechanisation of fonio post-harvest techniques

The delays observed during the first 2 years of the project were reduced, and all the planned trials were carried out.

2.3.3. WP3: Improvement of fonio processing and stabilisation techniques

The cumulative delays from the first 2 years of the project were also reduced for this package, and all the planned trials were carried out, thanks in particular to the 6-month extension of the project. In this way the transfer and field tests of the CSec-T "cross-flow" dryer and CSec-S "greenhouse" dryer in Senegal, Burkina Faso and Guinea took place during Q1 2016.

In terms of mechanisation of fonio degritting, the first "hydrolift" prototype degritter was manufactured and field tested on the premises of UCODAL in Bamako (Mali) during 2015.

Thanks to the 6-month extension of the project, a second prototype and a pilot lot of two hydrolift degritters were made to equip 3 other fonio processing SMEs, in Mali, Burkina Faso and Senegal respectively.

2.3.4. WP4: Innovation process in small processing plants

There were no particular delays in the execution of the WP4 activities.

2.3.5. WP5: Facilitation, coordination and communication

Because of the security and/or sanitary situation in certain partner countries (especially Guinea and Mali), the Steering Committee had to modify the initially planned meetings and workshops calendar. In the end, these modifications were not detrimental to the smooth running of the project.

2.3.6. Others activities

- ✓ **Half-way assessment**

A half-way assessment mission by 2 experts had been planned to analyse the suitability of the equipment (threshers, cleaners, degritters, dryers, etc.) tested by the small processing companies. Since the design and validation of the prototypes was delayed, and the first equipment was not installed in the field until 2015, the half-way assessment mission proved pointless. Given the good results obtained, from the initial trials on the prototypes designed (hydrolift degritter, greenhouse dryer and cross-flow dryer, etc.), it seemed preferable to use this item to ensure better dissemination of high-performance equipment to the various partners: dryers to Senegal, but also Burkina Faso and Guinea; hydrolift degritters to 2 companies in Bamako (Mali), but also to Burkina Faso (Bobo Dioulasso) and Senegal (Kédougou).

- ✓ **Final seminar**

A final seminar had been scheduled in Ouagadougou (Burkina Faso), but given the attacks which took place in this city in January 2016, the project Steering Committee decided to replace this event with a final meeting of the project partners in Montpellier (France).

2.4. Aval Fonio project results.

Observations on the execution and achievement of the activities

Certain technical activities may have been substantially delayed in their execution since the security and/or sanitary situation in some partner countries (Guinea, Mali, or even Burkina Faso, etc.) disrupted the launch or smooth running of the actions.

The WP1 surveys on fonio production and post-harvest systems in Guinea in the end proceeded more or less as planned despite the country at one time being hard hit by the Ebola virus. Thanks to the dedication of the partner IRAG, these surveys were conducted in 7 prefectures of Fouta Djallon, where fonio cultivation is very frequent.

In WP2 "Mechanisation of post-harvest techniques", the various planned activities were completed with very interesting results, although not all positive.

A fonio motor mower was tested in Guinea, but the results were dissatisfactory. So some further studies are required, with a view to mechanisation of fonio harvesting in the long term.

Fonio threshing tests were carried out. The Ricefan thresher was tested in Mali and Guinea, but the results were mediocre. The new trials conducted with the reconditioned ASSI thresher confirmed the good results already obtained during the previous fonio projects. Following on from the very good results obtained with the modified ASSI thresher, the mechanisation specialists have validated the machine for threshing fonio, and consider that it also seems economically profitable, especially under conditions in Guinea. The current machine, which is relatively bulky, may be suitable for easily accessible plain zones. For mountain zone, more compact threshers of the same type would need to be used, for ease of transport.

The cleaning trials with the rotary screen and winnowing channel confirmed the good performances of this equipment. Following on from the very good results obtained (throughput around 400 kg/h), the mechanisation specialists have validated this equipment for cleaning paddy fonio, and consider that it can be used for cleaning hulled and whitened fonio; the winnowing channel is also often coupled to the GMBF huller-whitener. The rotary screen and winnowing channel are versatile pieces of equipment which can be used on other cereals. Now both machines should be manufacturable by local tradesmen, thereby ensuring their distribution across numerous West African countries.

The technical results of WP3 "Improvement of fonio processing and stabilisation techniques" were the most numerous and the most innovative.

For activity 3 relating to mechanisation of washing and degritting, it was demonstrated, by tests in Montpellier and Bamako, that use of a simple electrical "cement mixer" type washer could implement an excess water mixing principle, similar to the one used in traditional manual washing of fonio. For degritting, the "hydrolift" degritter, designed by Cirad, meets the specifications that the researchers had set by ensuring a throughput of around 100 kg/h and a residual grit content in the grains of less than 200 ppm. Prototypes and pilot lot equipment were set up and tested in SMEs in Mali, Burkina Faso and Senegal. The private operators are satisfied with the good performances observed under actual conditions of use.

For activity 4 "drying", a cross-flow dryer (CSec-T) and a "greenhouse" dryer (CSec-S) were tested on the ESP-UCAD site in Dakar before being transferred to the field in eastern Senegal (CSec-T dryer to the group in Salémata and CSec-S dryer to the Koba Club group, Kédougou). The CSec-T dryer meets the specifications that the researchers had set by providing a load capacity of approximately 100 kg and a drying flowrate of 30 to 35 kg/h to dry wet processed fonio (white or precooked) from 35% to 10%. The 90 m² CSec-S greenhouse dryer equipped with 10 or more trays also meets the specifications set by providing a load capacity of approximately 300 to 350 kg for drying wet processed fonio (white or precooked) from 35% to 10% in 24 h. Furthermore, 2 CSec-T dryers were manufactured in Burkina Faso to be installed with 2 Burkinese SMEs (in Ouagadougou and Toussiana), and a small 20 m² CSec-S dryer was set up in the village of Pilimini in Guinea. The various private operators who were able to use the CSec-T and CSec-S dryers seem to have satisfied the performances observed under actual conditions of use.

For WP4 "The innovation process in small processing plants", the activities proceeded as planned and the "GMBF huller" innovation impact study were conducted in Burkina Faso and Mali. For the field studies,

Cirad and IRSAT requested the collaboration of the NGO “Afrique Verte” (Aprossa) in Burkina Faso and of the NGO “Afrique Verte” (Amassa) and the IER (Ms. F. Guindo) in Mali.

For WP5, activities 6.1 (Website) and 7.2. (Training the partners) had been carried out at the beginning of the project in accordance with the provisional programme. For the other activities some modifications were made to the calendar of the various meetings or workshops, as was described in paragraph 2.3 “Modified activities”. 2 items were modified from the initial project, relating in particular to the half-way point assessment mission and the organisation of a final seminar.

In terms of publications, certain results from the Aval Fonio project were covered by posters presented at various occasions, and were used to update the book “*Le fonio, une céréale africaine*” published in 2011 by Editions QUAE. The English version entitled “Fonio, an African cereal” was then published in July 2016 (Editions Cirad, IRAG).

2.5. Results for end beneficiaries and target groups

A host of private partners were associated with the project, especially producers, processors and women’s associations/groups, equipment manufacturers …

In Guinea, it was more the fonio producers which were associated from the beginning of the Aval Fonio project, since the activities of WP1 involved the upstream segment of the industry. Particular attention was paid to the village of Donghel Sigon (Mali prefecture, Fouta Djallon), where the producers own two large areas covering 170 ha and 250 ha, currently dedicated to fonio cultivation. Under WP2, a mechanical workshop Labé (M. Thierno Bela) was closely involved in the modifications made to certain equipment. Finally a group of women from the village of Pilimini (Koubia prefecture, Fouta Djallon) had a small-sized CSec-S greenhouse dryer installed.

In Senegal, it was women processors’ associations, unified in groups, which closely collaborated with the project through their involvement on the one hand with the CSec-T cross-flow dryer trials (group in Salémata), and on the other hand with the installation and monitoring of the CSec-S greenhouse dryer and hydrolift degritter (*Koba Club* group, Kédougou). The *Mamba Guirassy* technical institute in Kédougou also contributed to the final assembly of the hydrolift degritter.

In Mali, as in previous fonio projects, very close collaboration was established with the equipment manufacturer *IMAF*, which contributed to the activities from the beginning of the project. The joint actions in particular related to the manufacture or modification of numerous pieces of equipment or prototypes tested under the project: motor mower, Ricefan thresher, winnowing channel, rotary screen, “hydrolift” prototype degritters. Other equipment manufacturers were also able to participate in certain activities, such as *MOD Engineering* or the tradesman *Nana Philémon*. Several SMEs from Bamako were also closely involved in the various field tests conducted. These included in particular *UCODAL*, *Danaya Céréales* and *Dado Production*. These SMEs are the three leading fonio processing companies in Bamako (Mali) (see § 2.2.4).

In Burkina Faso, meetings were held with more than twenty mechanical manufacturing workshops in Bobo Dioulasso and Ouagadougou during surveys conducted under WP4. Very close collaboration was established with the equipment manufacturer SOLDEV in Bobo Dioulasso for manufacturing CSec-T dryers and the partial production and the assembly of the hydrolift degritter. Special collaboration was also established with the fonio processing unit newly established in Bobo Dioulasso, where the hydrolift degritter was installed and which invested in a CSec-T cross-flow dryer. Fifteen or so fonio processors from western Burkina Faso and Ouagadougou received a training session on how to use the CSec-T dryer. Two SMEs, “*Tout Super*” in Toussiana and *EOBA* in Ouagadougou, were selected to receive CSec-T dryers because of their long-standing collaboration with the researchers who since the early 2000s have been working to improve the fonio industry in West Africa.

2.6.Products achieved by the project

2.6.1. Reports and publications

- ✓ **Reports**

Cruz J-F., Goli T, Ferré T. 2016. Rapport annuel 2015-2016. Projet Aval Fonio. Cirad, Montpellier, 47p. (Versions française et anglaise).Cruz J-F. 2013. Réunion de démarrage et ateliers. Projet Aval Fonio. Cirad, Montpellier, 20 p. + annexes

Ferré T., Medah I. 2016. Processus d'innovation dans les petites industries de transformation. Rapport d'activités 2015 et 2016. Projet Aval Fonio. Cirad, Montpellier. 14 p.

Béavogui F., Camara S., Diallo A. 2015. Rapport annuel WP1. Analyse des systèmes de production et des systèmes post-récolte en Moyenne. Projet Aval Fonio. IRAG, Conakry, Guinée. 13 p.

Cruz J-F. 2015. Rapport annuel 2014. Projet Aval Fonio. Cirad, Montpellier, 36 p. (Versions française et anglaise).

Cruz J-F., Kébé C. M. F. 2015. Rapport de l'atelier de Dakar (Sénégal). Projet Aval Fonio. Cirad, Montpellier, 32 p.

Béavogui F., Camara S., Diallo A. 2014. Rapport annuel WP1. Analyse des systèmes de production et des systèmes post-récolte en Moyenne. Projet Aval Fonio. IRAG, Conakry, Guinée. 23 p. + annexes

Cruz J-F. 2014. Rapport de la 1ère réunion annuelle. Projet Aval Fonio. Cirad, Montpellier, 25 p.

Cruz J-F. 2014. Rapport annuel 2013. Projet Aval Fonio. Cirad, Montpellier, 36 p. (Versions française et anglaise).

Cruz J-F., Goli T, Ferré T., Thaunay P. 2014. Rapport de l'atelier des WP1 à 4 à Bamako (Mali). Projet Aval Fonio. Cirad, Montpellier, 19 p.

Béavogui F., Diallo T.A., Camara S., Thaunay P. 2013. Compte – rendu annuel des activités de l'IRAG Projet Aval Fonio. IRAG, Conakry, Guinée. 10 p.

Cruz J-F. 2013. Réunion de démarrage et ateliers. Projet Aval Fonio. Cirad, Montpellier, 20 p. + annexes

Cruz J-F. 2013. Rapport intermédiaire. Projet Aval Fonio. Cirad, Montpellier, 20 p.

Cruz J-F., Goli T, Ferré T. 2013. Rapport de l'atelier des WP3&4 à Ouagadougou (Burkina Faso). Projet Aval Fonio. Cirad, Montpellier, 25 p.

Diallo T.A., Thaunay P. 2013. Compte –rendu annuel des activités sur la mécanisation des techniques post-récolte du fonio en Guinée. Projet Aval Fonio. IRAG, Conakry, Guinée. 4 p.

- ✓ **Mission reports**

Diallo A. 2016. Compte rendu de mission à Bamako (Mali) et Bobo Dioulasso (Burkina). Adapter et valider des séchoirs pour les PME transformatrices. Projet Aval Fonio. ESP-Ucad, Dakar, Sénégal. 10 p.

Diallo A. 2015. Compte rendu de mission à Kédougou. Implantation d'un séchoir solaire CSec-S. Projet Aval Fonio. ESP-UCAD, Dakar, Sénégal. 10 p.

Rivier M. 2015. Rapport de mission à l'ESP-UCAD au Sénégal. Essais de validation des séchoirs à flux traversant (CSec-T) et « serre solaire » (CSec-S). Projet Aval Fonio. Cirad. Montpellier. 20p.

Cruz J-F. 2013. Rapport de mission au Sénégal. Projet Aval Fonio. Cirad, Montpellier, 7 p.

Diallo T.A., Thaunay P., Loua F. 2013. Compte –rendu d'essais de matériel de récolte de battage et de nettoyage du fonio en Guinée. Projet Aval Fonio. IRAG, Conakry, Guinée. 8 p.

Kane C., Anne A. 2013. Compte rendu de mission au Mali. Rencontre avec des transformatrices de fonio et des constructeurs d'équipements. Projet Aval Fonio. ESP-Ucad, Dakar, Sénégal. 10 p.

Kebe C. M. F., Cissé M., Ayessou N. 2013. Compte rendu de mission à Salémata, Kédougou et Kayes. Projet Aval Fonio. ESP-UCAD, Dakar, Sénégal. 8 p.

Thaunay P. 2013. Formation Méthode de conception d'équipements à l'ESP-Ucad. Projet Aval Fonio. Activité 7.2., Cirad, 37 p. + annexes

- ✓ **Interns' reports**

Chtioui M., 2015. Analyse de la diffusion et des effets d'une innovation au Burkina Faso et au Mali : le décortiqueur de fonio « GMBF ». Mémoire de fin d'études Ingénieur. Ecole Supérieure d'Agro-Développement International (ISTOM). Cergy-Pontoise, France. 92 p. + annexes.

Coulibaly K., 2014. Analyse des processus d'innovation dans les petites et moyennes entreprises de transformation de fonio à Bamako. Projet Aval Fonio. Mémoire de fin d'étude. Master 2 Economie Rurale et Stratégies des Entreprises Agroalimentaires (ERSEA). Université de Montpellier, France. 45 p.

Blanc N. 2013. Recherche et étude de principes permettant le lavage et dessablage du fonio. Master 1 de mécanique. Université de Montpellier 2. Cirad. Montpellier, France. 58 p. + annexes

Gaucher S. 2013. Les contraintes au développement des entreprises de transformation du fonio au Sénégal Oriental. Projet Aval Fonio. Mémoire de fin d'étude. Montpellier SupAgro. Spécialité Systèmes Agricoles et agroalimentaires durables au Sud (SAADS). Option: Industrie agroalimentaire au Sud (IAAS) Montpellier, France. 38 p. + annexes.

Martin C. 2013. Analyse des processus d'innovation dans la transformation du fonio au Burkina Faso. Projet Aval Fonio. Mémoire de fin d'étude. Montpellier SupAgro. Spécialité Systèmes Agricoles et agroalimentaires durables au Sud (SAADS). Montpellier, France. 110p. + annexes

- ✓ **Posters and brochures**

Cruz J.-F., Ferré T., Medah I., Guindo F., Thaunay P., Goli T. 2016. Valorisation du fonio, Impact du décortiqueur GMBF. Projet Aval Fonio. Cirad, IRSAT, ESP/UCAD, IER, IRAG. Forum de la Recherche Scientifique et des Innovations Technologiques (FRSIT), Ouagadougou, Burkina Faso.

Cruz J.-F., Méot J.-M., Rivier M., Kébé C. M. F., Anne A., Diallo A., Delpech A., Ferré T., Medah I., Havard M. 2016. Séchoir à flux traversant CSec-T, séchage des produits granuleux. Projet Aval Fonio. Cirad, IRSAT, ESP/UCAD, IER, IRAG. Forum de la Recherche Scientifique et des Innovations Technologiques (FRSIT), Ouagadougou, Burkina Faso.

Cruz J.-F., Rivier M., Diallo A., Ferré T., Kébé C. M. F., Anne A., Sambou V., Medah I., Méot J.-M. 2016. Séchoir serre solaire CSec-S. Projet Aval Fonio. Cirad, IRSAT, ESP/UCAD, IER, IRAG. Forum de la Recherche Scientifique et des Innovations Technologiques (FRSIT), Ouagadougou, Burkina Faso.

Cruz J.-F., Thaunay P., Goli T., Fleuriot J.-P., Delpech A., Ferré T., Medah I., Guindo F. 2016. Valorisation du fonio, le dessableur hydrolift. Projet Aval Fonio. Cirad, IRSAT, ESP/UCAD, IER, IRAG. Forum de la Recherche Scientifique et des Innovations Technologiques (FRSIT), Ouagadougou, Burkina Faso.

Cruz J.-F., Kébé C. M., Cissé M., Sambou V., Béavogui F., Diallo T. A., Goli T., Thaunay P., Ferré T., Medah I., Guindo F., Soufountera M. 2014. Valorisation du fonio. Cirad, ESP/UCAD. Forum International sur la promotion des innovations et des partenariats dans le secteur agro-alimentaire et des agro-ressources (FINNOVAR), Dakar, Sénégal.

Cruz J.-F., Kébé C. M. F., Goli T., Diallo T. A., Guindo F., Medah I., Ferré T., Thaunay P., Béavogui F., Sambou V., Cissé M., Soufountera M. 2014. Mécanisation post-récolte du fonio. Congrès AFTER, projet européen sur la Valorisation des produits traditionnels africains. Dakar, Sénégal.

Goli T., Thaunay P., Ricci J., Prades A., Bore Guindo F., Babre D., Van de Lee A., Cruz J.-F. 2014. Procédés de dessablage du fonio: Détermination de la teneur en sable. Congrès AFTER, projet européen sur la Valorisation des produits traditionnels africains. Dakar, Sénégal.

Cruz J-F, Ferré T., Medah I., Goli T. 2013. Valorisation d'une céréale africaine: le fonio. (Digitaria exilis Stapf). Cirad, Irsat, Syal. Congrès International des Systèmes agroalimentaires localisés (SYAL), Florianopolis, Brésil.

- ✓ **Book**

Cruz J-F, Béavogui F., Dramé D., Diallo T.A. 2016. Fonio, an African cereal. Editions Cirad/IRAG, Montpellier, France, 153 p.

- ✓ **Film**

Morlet N., with the collaboration of Cruz J.-F., Fonio, 2016.

2.6.2. Deliverables

The Aval Fonio project deliverables, currently being drawn up, are as follows:
Deliverable 1. Typology of production and post-harvest systems in Guinea.
Deliverable 2. Main constraints for fonio production in Guinea and prospects for development
Deliverable 3. Mechanisation of fonio harvest and threshing.
Deliverable 4. Mechanisation of fonio cleaning.
Deliverable 5. Mechanisation of fonio washing and degritting operations
Deliverable 6. User guide for the "hydrolift" fonio degritter
Deliverable 7. Manufacture dossier for the "hydrolift" fonio degritter
Deliverable 8. Quantification of grit in fonio
Deliverable 9. Fonio drying. The Csec-S greenhouse dryer
Deliverable 10. Adaptation and assembly dossier for the Csec-S greenhouse dryer
Deliverable 11. Company trial of Csec-S greenhouse dryer
Deliverable 12. Fonio drying. The CSec-T cross-flow dryer
Deliverable 13. CSec-T dryer manufacturing plans
Deliverable 14. Company trial of the CSec-T cross-flow dryer
Deliverable 15. User manual for the CSec-T dryer
Deliverable 16. Training guide for using the CSec-T dryer
Deliverable 17. Fonio processing companies and innovations in Burkina Faso
Deliverable 18. Fonio processing companies and innovations in Mali
Deliverable 19. GMBF fonio huller impact study

2.6.3. Equipment

The list of the main fonio harvesting and post-harvesting equipment designed and/or adapted under the Aval Fonio project is as follows.

- 1 rice motor mower (model JD 170 F) manufactured in Guinea and tested by IRAG in Bareng
- 1 *RiceFan* (Votex) thresher, manufactured by IMAF and tested at IER in Mali, and then IRAG in Guinea
- 1 reconditioned ASSI thresher tested by IRAG at Donghel Sigon, in Fouta Djallon (Guinea)
- 1 reconditioned Alvan Blanch winnower tested by IRAG in Bareng
- 1 winnowing channel manufactured by IMAF in Mali and tested by IRAG in Bareng (Guinea)
- 1 rotary screen manufactured by IMAF in Mali and tested by IRAG in Bareng (Guinea)
- 1 GMBF huller manufactured by IMAF in Mali and set up for demonstration at IRAG Bareng in Guinea
- 1 GMBF huller manufactured by IMAF in Mali and set up for demonstration in the Donghel Sigon producers' group in Fouta Djallon (Guinea)
- 1 rotary washer (cement mixer type) tested at Cirad (Montpellier)
- 1 rotary washer (cement mixer type) tested at IER in Mali
- 1st *hydrolift* degritter prototype manufactured by Cirad and IMAF, and tested on the premises of UCODAL in Bamako (Mali)
- 2nd *hydrolift* degritter prototype manufactured by Cirad and IMAF, and tested on the premises of Danaya Céréales in Bamako (Mali)
- 1st *hydrolift* degritter manufactured by Cirad and SOLDEV, and set up by Cirad and IRSAT on the premises of the fonio processing unit (UTF) in Bobo Dioulasso (Burkina Faso)
- 2nd *hydrolift* degritter manufactured by Cirad and SOLDEV, and set up by Cirad and the Mamba Guirassy technical institute (Kédougou) at the Koba Club group in Kédougou (eastern Senegal).
- 1 CSec-T cross-flow dryer manufactured in Dakar, and set up at ESP-UCAD and then on the premises of a group in Salémata (eastern Senegal).
- 2 CSec-T cross-flow dryer dryers manufactured by SOLDEV, tested by Cirad and IRSAT with the collaboration of ESP-UCAD, and set up on the premises of the small companies "Tout Super" in Toussiana, and EOBA in Ouagadougou (Burkina Faso).
- 1 CSec-S greenhouse dryer, manufactured by Filclair (France) and installed and then tested, with the collaboration of Cirad, on the ESP-UCAD site in Dakar (Senegal)
- 1 CSec-S greenhouse dryer, manufactured by Filclair (France) and installed and then tested by ESP-UCAD on the premises of the Koba Club group in Kédougou (eastern Senegal).
- 1 small CSec-S greenhouse dryer, manufactured by Serre Tonneau (France), and installed by the NGO Adesag with the collaboration of IRAG in the village of Pilimini in Guinea.

2.7. Contract of more than 10,000 euros

In the project, the only expense of more than €10 000 related to the purchase of a pick-up truck by IRAG in Guinea in 2013. The purchase was done in accordance with the procedure consultant 3 suppliers of vehicles. The offers were:

- Seta Guinea: Mitsubishi L 200 DC for a total of 32 443 euros
- Le carrefour des automobiles: Toyota Hilux for a total of 32 750 euros
- Groupe Société de commerce: Nissan Pick up for a total of 35 690 euros.

The lowest bid was chosen and the purchase of the Mitsubishi L 200 DC to Seta Guinea has been achieved.

2.8. Further action

The various project partners will seek to continue activities in the fonio post-harvest segment. IRAG in Guinea has a "fonio" specific programme going back many years, through which it can seek to disseminate and harness the results obtained, in terms of threshing and cleaning the grains, as well as in the field of hulling and drying the processed products. In Senegal, ESP-UCAD should be able to develop a project for distributing the dryers (greenhouse and cross-flow), seeking funding from the national authorities, such as the FNRAA (National fund for agricultural and agribusiness research). In Mali, IER/LTA which collaborates closely with the processing SMEs and producers' groups should be able to contribute to disseminating fonio post-harvest and processing technologies (threshers, cleaners, hullers, etc.) through the West Africa Agricultural Productivity Plan (WAAPP). In Burkina Faso, IRSAT in collaboration with ANVAR and the equipment manufacturers (REMICO, Agri-Equipement, SOLDEV, etc.) identified during the Aval Fonio project should also be able to contribute to disseminating the fonio post-harvest and processing technologies (GMBF huller, CSec-T cross-flow dryer, etc.)

2.9. Gender aspect

In the fonio industry, women play a very important role as producers (some women have their own fields) and as processors or traders, especially in the poorest zones. Mechanisation of certain post-harvest operations, often reserved for women, facilitates their daily chores. Under the Aval Fonio project, the development of equipment (threshers, cleaners, hullers, washers, degritters, etc.) relating to often arduous post-harvest operations can directly improve the wellbeing and quality of life of women. Training in how to use the equipment was organised for women processors' groups (e.g. using the CSec-T dryer). The modernisation of the industry favours the emergence of small companies creating jobs, and the creation of women fonio processors' groups.

2.10. Monitoring and assessment

The performances of the equipment during the development phase was monitored by the researchers themselves. During the equipment field tests, the equipment was monitored by the researchers and technicians from the various project partners. The equipment was then assessed by the operators themselves, who were able to directly appreciate its advantages. The private operators (producers, women processors, SMEs and groups, etc.) were often highly satisfied with the good equipment performances obtained under actual conditions of use.

2.11. Knowledge gained

The various partners realised the benefit of the participatory approaches both during the surveys conducted in rural areas in characterising production and post-harvest systems, and for developing fonio post-harvest equipment. Equipment manufacturers were trained in manufacturing machinery, and potential users (processors, SMEs and groups, etc.) were closely associated with setting up equipment and monitoring its operation. This participatory approach provided real-time, precise assessment of the performances of the machinery by the operators themselves.

3. Partners and other cooperation

3.1. Relations between the Aval Fonio project partners

During the Aval Fonio project, the coordinators did not encounter any particular difficulties with the partner institutions in executing the activities. On the contrary, the coordinators can be pleased at the interest, vigour and good spirit of collaboration demonstrated by all the work package supervisors and all the agents involved in the project. For the researchers involved, the Aval Fonio project was an opportunity to

strengthen ties already created in previous fonio projects (Cirad, IER, IRAG and IRSAT), initiate precious collaboration with ESP-UCAD in Senegal and meet a CNTA researcher from Burundi. The main regret for the coordinators and the partners was not having the opportunity to travel to Guinea, the main fonio producer country, to meet directly with the institution IRAG and the fonio industry operators.

3.2. Ongoing collaboration

Cirad has cooperated for many years with the action partners, and the Aval Fonio project made it possible to strengthen the fruitful collaboration already established during previous international projects conducted in fonio during the 2000s. So it appears certain that these good relations between the partner institutions will be strengthened, and will be useful for jointly setting up new research projects on fonio or other industries or themes.

3.3. Relations with the State authorities in the project countries

Throughout the project, the main difficulties encountered were due to difficult security or sanitary situations in certain partner countries, such as Guinea, Mali and also Burkina Faso.

In particular, the CNTA support mission, initially planned to study to what degree the equipment developed for fonio could benefit finger millet producers, had to be abandoned because of security problems in Burundi.

3.4. Relations with any other organisation involved in the project implementation

- **Associates**

The National Centre for Agribusiness Technology (CNTA), Burundi. In 2013, a specialist in post-harvest technologies from CNTA, Mr. Ntahomvukiye Stany, took part in the Aval Fonio project kick-off meeting and in the WP2 workshop. This researcher also participated in the project 2014 annual meeting in Montpellier (France), and the 2015 annual meeting in Ouagadougou (Burkina Faso). A study mission to Burundi was planned by Cirad (J-F Cruz) for 2015 or 2016 to carry out a review of the finger millet industry in collaboration with CNTA. Yet because of the growing insecurity prevailing in this country since early 2015, this mission was deferred several times, and ended up being cancelled.

The Institute for Hot Regions (IRC-SupAgro) in Montpellier (France) closely collaborated with the activities of WP4 in partnership with IRSAT and Cirad. IRC SupAgro in particular contributed to the scientific and educational supervision of an intern student who spent more than 5 months in Burkina Faso in 2013.

- **End beneficiaries and target groups**

A host of private partners were associated with the project, especially producers, processors and women's associations unified in groups, equipment manufacturers, etc.

In Guinea, it was more the fonio producers which were associated from the beginning of the Aval Fonio project, since the WP1 activities related to the upstream segment. Particular attention was paid to the village of Donghel Sigon in Fouta Djallon (Mali prefecture), where the producers own two large areas of 170 ha and 250 ha, currently dedicated to fonio cultivation. Under WP2, a mechanical workshop from Labé (Mr. Thierno Bela) was closely involved in the modifications made to certain equipment. Finally a group of women from the village of Pilimini (Koubia prefecture, Fouta Djallon) had a small-sized CSec-S greenhouse dryer installed.

In Senegal, it was women processors' associations, unified in groups, which closely collaborated with the project through their involvement on the one hand with the CSec-T cross-flow dryer trials (group in Salémata), and on the other hand with the installation and monitoring of the CSec-S greenhouse dryer and hydrolift degritter (*Koba Club* group, Kédougou). The *Mamba Guirassy* technical institute in Kédougou also contributed to the final assembly of the hydrolift degritter.

In Mali, as in previous fonio projects, very close collaboration was established with the equipment manufacturer *IMAF*, which was involved in the activities from the beginning of the project. The joint actions in particular related to the manufacture or modification of numerous pieces of equipment or prototypes tested under the project: motor mower, Ricefan thresher, winnowing channel, rotary screen, "hydrolift" prototype degritters. Other equipment manufacturers were also able to participate in certain activities, such as *MOD Engineering* or the tradesman *Nana Philémon*. Several SMEs from Bamako were also closely involved in the various field tests conducted. These included in particular *UCODAL*, *Danaya Céréales* and *Dado Production*. These SMEs are the three leading fonio processing companies in Bamako (Mali) (see § 2.2.4).

In Burkina Faso, meetings were held with more than twenty mechanical manufacturing workshops in Bobo Dioulasso and Ouagadougou during surveys conducted under WP4. Very close collaboration was established with the equipment manufacturers SOLDEV and A. Souaré in Bobo Dioulasso for manufacturing CSec-T dryers and the partial production and the assembly of the hydrolift degritter. Special collaboration was also established with the fonio processing unit (UTF) newly established in Bobo Dioulasso, where the hydrolift degritter was installed and which invested in a CSec-T cross-flow dryer. Fifteen or so fonio processors from western Burkina Faso and Ouagadougou received a training session on how to use the CSec-T dryer. Two SMEs, "*Tout Super*" in Toussiana and *EOBA* in Ouagadougou, were selected to receive CSec-T dryers because of their long-standing collaboration with the researchers who since the early 2000s have been working to improve the fonio industry in West Africa.

- **Other third parties involved (NGOs, etc.)**

Under the Aval Fonio project activities, and especially for WP3 and WP4, the researchers have closely collaborated with NGOs, such as in Burkina Faso with the NGO Afrique Verte, Aprossa *(Association for the Promotion of food security and sovereignty in Burkina)*, in Mali with the NGO Afrique Verte, Amassa *(Malian association for food security and sovereignty)* and Guinea with the NGO ADESAG (*Association for the development of socially responsible enterprise in Africa and Guinea*).

3.5. Links with other actions

As part of an in-house project, Cirad has developed a method known as ImpresS, which is aimed at assessing the contribution of research to development through innovation case studies based in multi-player environments. During this programme, two Aval Fonio project researchers (Ignace Medah from IRSAT and Thierry Ferré from Cirad) benefitted from methodological support and training, with the participation of two research schools. By relying on this ImpresS methodology, the Aval Fonio project WP4 team was able to analyse the innovation process and the impacts of the GMBF fonio huller innovation.

Furthermore, the NGOs Afrique Verte Aprossa (Burkina Faso) and Afrique Verte Amassa (Mali) also benefitted from this ImpresS methodology, and were thus able to contribute to the execution of the GMBF huller case study under the Aval Fonio project. The lessons drawn from this innovation case study strongly contributed to improving support practices for the dissemination of the "hydrolift degritter" and "CSec-T dryer".

3.6. Previous EU grants

From 2006 to 2008, Cirad and its partners (IER in Mali, IRAG in Guinea, CIRDES in Burkina Faso) ENDA-Graf in Senegal, Wageningen University in the Netherlands and CRAW in Belgium) received a contribution of 900,000 euros under the FP6 - INCO-Dev-2 programme to conduct a project entitled "*Upgrading quality and competitiveness of the fonio industry in West Africa*".

This INCO Fonio project was able to work on the entire fonio industry, with particular focus on the following points:

- physical characteristics of fonio and quality criteria of precooked fonio for the local and export markets,
- initial approach to upgrading fonio drying equipment,
- determining the nutritional value of fonio and contributing to the dietary and nutritional status,
- determining the characteristics of demand for innovative African products and of the export markets,
- typology of fonio processing SMEs and procurement systems
- characterising the socio-technical environment and the strategies of the fonio producers,
- cataloguing of some ecotypes of fonio.

The Aval Fonio project followed on from this INCO Fonio international project, with reference to its conclusions which recommended developing new research on themes not yet covered, or technologies not yet fully developed. This is precisely what the Aval Fonio project has achieved, in part.

3.7. Cooperation with contracting authority

During the Aval Fonio project, the coordinators did not encounter any particular difficulties with the contracting authority in providing funds to enable the activities to proceed smoothly. The coordinators acknowledge the regard demonstrated by this authority in extending the project by 6 months, and thereby enabling numerous activities to produce tangible results (validation of equipment performance, such as the "hydrolift" degritter, and the cross-flow and greenhouse dryers).

4. Visibility

4.1. Aval Fonio project website

The website (in French and English) dedicated to the Aval Fonio project (http://aval-fonio.cirad.fr/projet/presentation) refers to the funding granted by the African Union (EuroAid procedure), and links to these institutions have been installed.

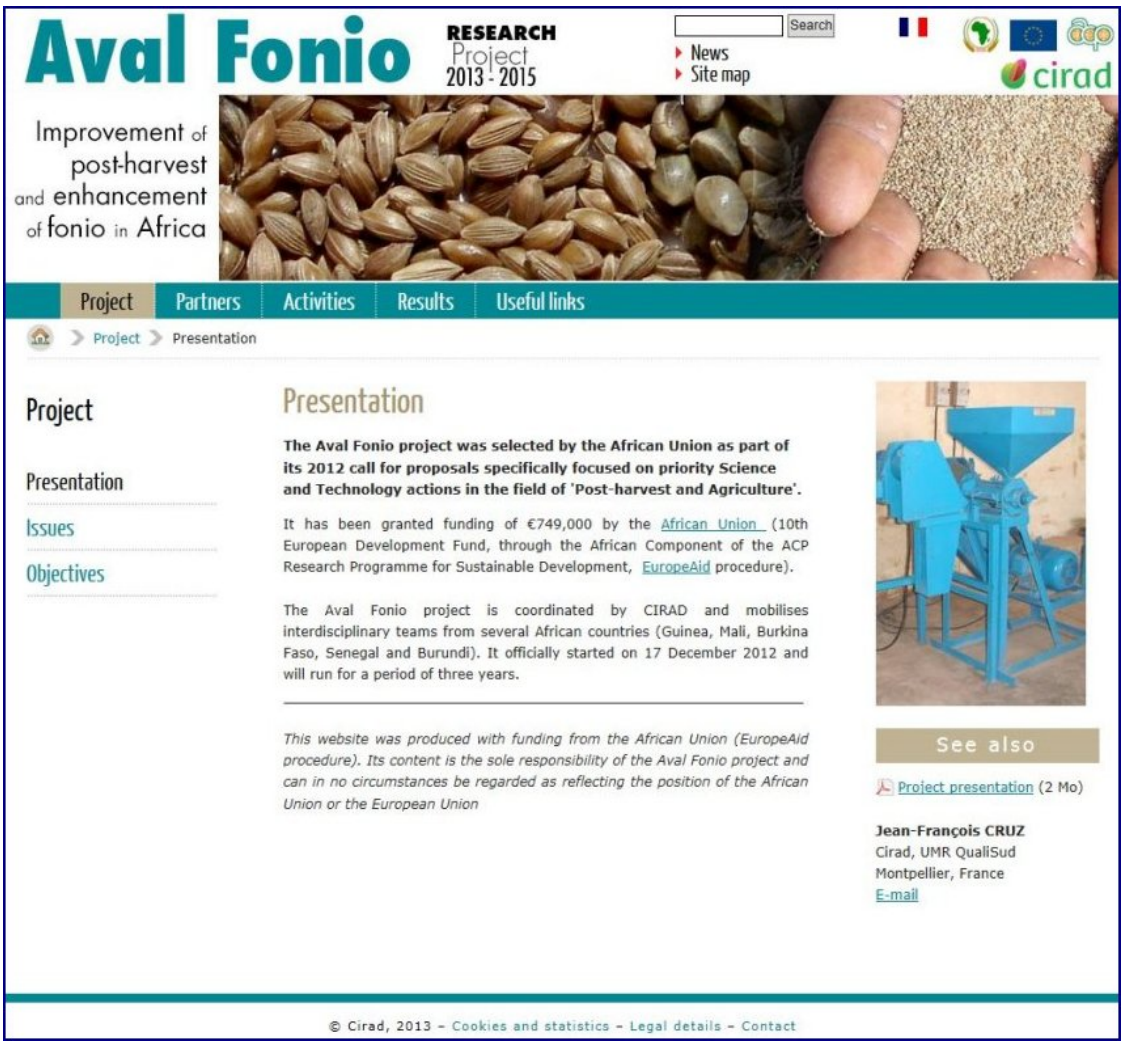


Figure 36. Screenshot of "presentation" page of the Aval Fonio website (© Cruz, Cirad)

4.2. Participation in international congresses

- ***"6th International Congress of Systèmes Agroalimentaires Localisés (SYAL)* Florianopolis (Brazil)**

Two Cirad researchers participated in the 6th International Congress of Systèmes Agroalimentaires Localisés (SYAL) held in Florianopolis (Brazil) in May 2013. They presented a poster referring to the "Aval Fonio" project:

Poster

Cruz J-F, Ferré T., Medah I., Goli T. 2013. Valorisation d'une céréale africaine: le fonio (Digitaria exilis Stapf). Cirad, Irsat, Syal. Congrès International des Systèmes agroalimentaires localisés (SYAL), Florianopolis, Brésil.

See : http://aval-fonio.cirad.fr/resultats/publications

- ***"Origin, Diversity and Territories" forum*, Turin (Italy)**

Aval Fonio project researchers took part in the "Origin, Diversity and Territories" forum (http://origin-for-sustainability.org/en/) held in Turin (Italy) from 21 to 23 October 2014. Cirad (T. Ferré) and ESP-UCAD (F. Kébé) presented the Aval Fonio project activities.

- **FINNOVAR international forum, Dakar (Senegal)**

Researchers from ESP-UCAD (F. Kébé and M. Cissé) and Cirad (Ms. S. Gaucher) took part in FINNOVAR (International Forum on Innovations and Partnerships Promotion in Agribusiness and Agro-resources), which was held in Dakar (Senegal) in July 2014.

Poster

Cruz J.-F., Kébé C. M., Cissé M., Sambou V., Béavogui F., Diallo T. A., Goli T., Thaunay P., Ferré T., Medah I., Guindo F., Soufountera M. 2014. Valorisation du fonio. Cirad, ESP/UCAD, Irag, Irsat, IER/LTA. Forum International sur la promotion des innovations et des partenariats dans le secteur agro-alimentaire et des agro-ressources (FINNOVAR), Dakar, Sénégal.

- **AFTER international congress, Dakar (Senegal)**

Aval Fonio project researchers from Cirad (T. Goli) and from ESP-UCAD (F. Kébé F. and M. Cissé) took part in the first international congress on promoting traditional African foods (AFTER project) organised in Dakar (Senegal) in November 2014. At this event, two communications were presented in poster form:

Posters

Cruz J.-F., Kébé C. M. F., Goli T., Diallo T. A., Guindo F., Medah I., Ferré T., Thaunay P., Béavogui F., Sambou V., Cissé M., Soufountera M. 2014. Mécanisation post-récolte du fonio. Cirad, ESP/UCAD, Irag, IER/LTA, Irsat. Congrès international sur la Valorisation des aliments traditionnels africains, Projet AFTER, novembre 2014. Dakar, Sénégal.

Goli T., Thaunay P., Ricci J., Prades A., Bore F.G., Babre D., Van de Lee A. et Cruz J.-F. 2014. Procédés de dessablage du fonio : détermination de la teneur en sable. Congrès international sur la Valorisation des aliments traditionnels africains. Projet AFTER, novembre 2014, Dakar, Sénégal.

See: http://aval-fonio.cirad.fr/resultats/publications

4.3. Publications and other works

In 2011, a book entitled "*Le fonio, une céréale africaine*" was published by Editions QUAE. This document, the first book dedicated exclusively to fonio, addresses all the aspects of this small cereal, from cultivation to processing. In July 2016, the English version entitled "Fonio, an African cereal" was published (Editions Cirad, IRAG). This work summarises around twenty years of research conducted in West Africa, under various international projects including the Aval Fonio project (see § 2.2.5, figure 53).

Reference

Cruz J-F, Béavogui F., Dramé D., Diallo T.A. 2016. Fonio, an African cereal. Editions Cirad/IRAG, Montpellier, France, 153 p.

A short documentary film was also produced:

Reference

Morlet N. Cruz J.-F., Fonio, 2016.

4.4. Receiving visitors at the Cirad agrifood technology platform

The Cirad agrifood technology platform receives a host of visitors all year round, and takes part in the Science Festival held in France in October. At each event, the Aval Fonio Project Coordinator (Cruz J-F.) presents to dozens of visitors the theme "Rice and fonio in all their states", broadly covering fonio post-harvest research technologies, and referring specifically to the Aval Fonio project.

The European Commission may wish to publicise the results of Actions. Do you have any objection to this report being published on the EuropeAid website? If so, please state your objections here

No objections

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