Novel Food Products using Quinoa

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Content

IYQ-2013, an accelerator of global expansion, *and after*?

I/ Quinoa, a small grain but a diversity of uses

II/ Feedback on the two objectives of the IYQ

II/ Gaps and Needs for the future of Quinoa food products

Some key introductory points

Quinoa Genetic Diversity = diversity of agroecosystem for cultivating the crop

Diversity of Farming Systems = selection of quinoa's landraces for a diversity of dishes

Diversity of Dishes = diversity of transformation and preparation of quinoa grains

Chenopodium quinoa Willd. evolved from a **complex process** of biological, geographical, social and cultural interactions that determines its ***current*** and ***future*** **genetic diversity**

I/ QUINOA,
a small quality grain with a diversity of uses

It all begins in the peasants' fields…

MECHANIZED THRESHING

GRAINS READY for POST-HARVEST PROCESSES

After, other constraints …

POST-HARVEST AND AGRIBUSINESS

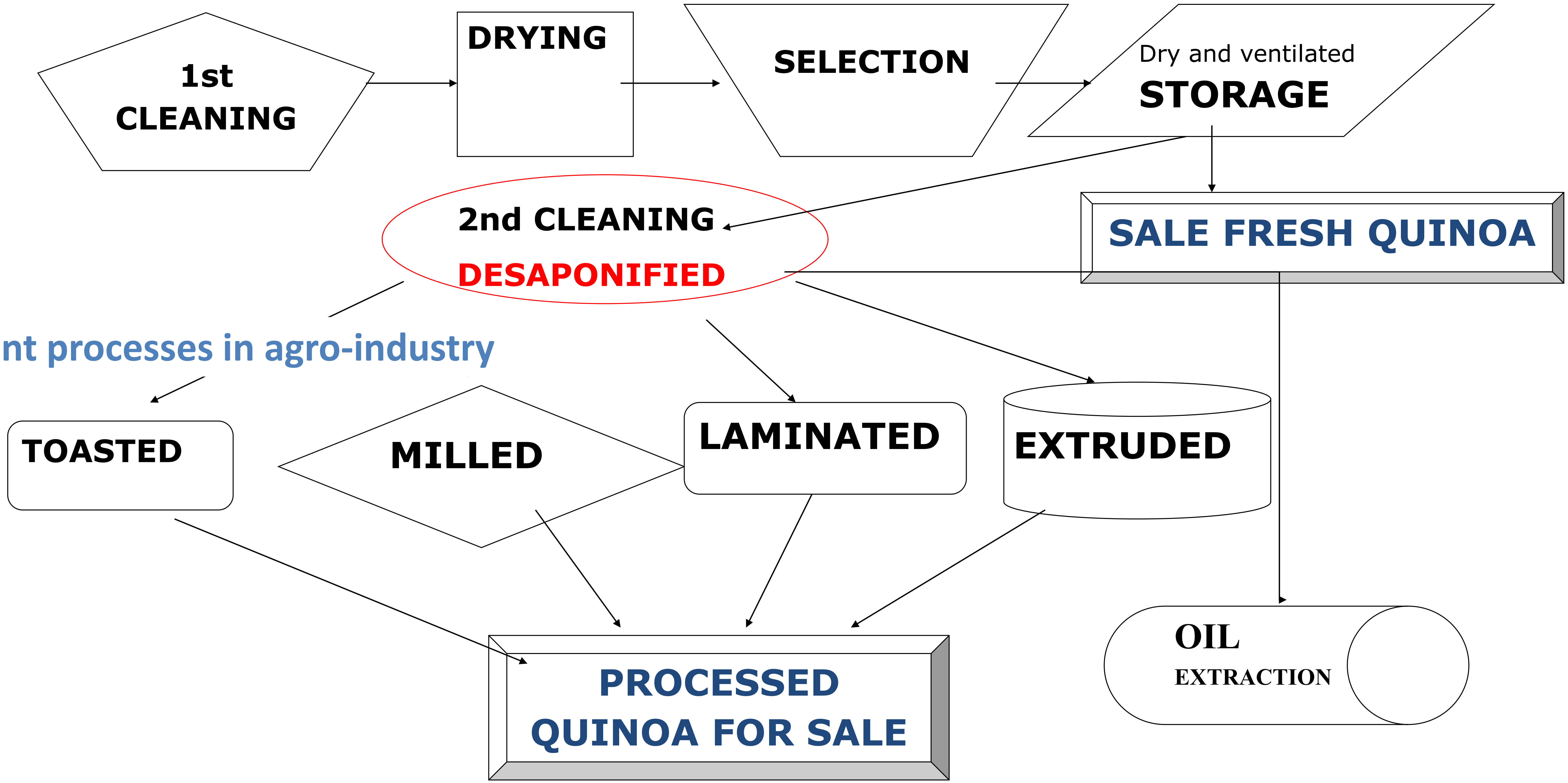
- **Post-harvest** transformation and **agribusiness** industry are activities of great importance in the production and transformation process of Andean grains and especially for quinoa

=> *the success to obtain the* ***best quality of the grain*** *for direct consumption, transformation and marketing depends on the* ***different steps of the process***

… Not only SIZE and COLOR !

Simplified flowchart of post-harvest and quinoa processing

1- Important stages of the postharvest



FIRST CLEANING

Process to remove all the impurities that accompany the grain.

=> *oscillating screens, rotary screens, pneumatic separators and/or gravity separators are used*

There is a special equipment called a destoning machine, to remove the stones or grit that the grain may have.

The impurities in the grain should not be greater than 1%.

DRYING

Once quinoa is clean, the humidity is around 16%, so it needs to be dried, as excessive humidity can cause yellowing, fermentation or germination of grains.

The humidity to store the grain should not exceed 12%.

Solar, gas, biogas and wood-fired dryers are used for drying.

SELECTION AND CLASSIFICATION

When the grain is dry, **selection and classification** are carried out, since quinoa produces *large, medium and small grains*. Likewise, there is the presence of *immature and broken grains*.

This classification will allow a better use of grains:

- **small grains** for milling and processed products from flour
- **medium grains** for semolina, flakes, expanded, pop quinoa and other uses in which the whole grain is not visible,
- **large grains** (***+ extra large***) for pearl quinoa and be bagged as a natural grain.

For exporting grains to the global market, the grain size is determined according to the diameter and classified in 4 categories (tab.1)

TABLE 1. DETERMINATION OF QUINOA GRAIN SIZE (Peruvian standard)

TAMAÑO	DIAMETRO PROMEDIO DEL GRANO (mm)	MALLA
Extra grande	mayor a 2.0	85% retenido en malla ASTM10
Grande	mayor a 1.7 hasta 2.0	85% retenido en malla ASTM12
Mediano	mayor a 1.4 hasta 1.69	85% retenido en malla ASTM14
Pequeño	menor a 1.4	85% pasa por malla ASTM14

STORAGE

Quinoa should be stored at a grain humidity of no more than 12%, in clean warehouses, on wooden pallets, adequately ventilated and in appropriate containers, not plastic or polypropylene, preferably metal silos that will prevent the presence of rodents and moths. It is not advisable to stock too more quantities; because they hinder ventilation and facilitate the conservation of humidity and can produce inappropriate odors to the product.

AT THIS STEP,
We only have fresh quinoa grain
(not desaponified)

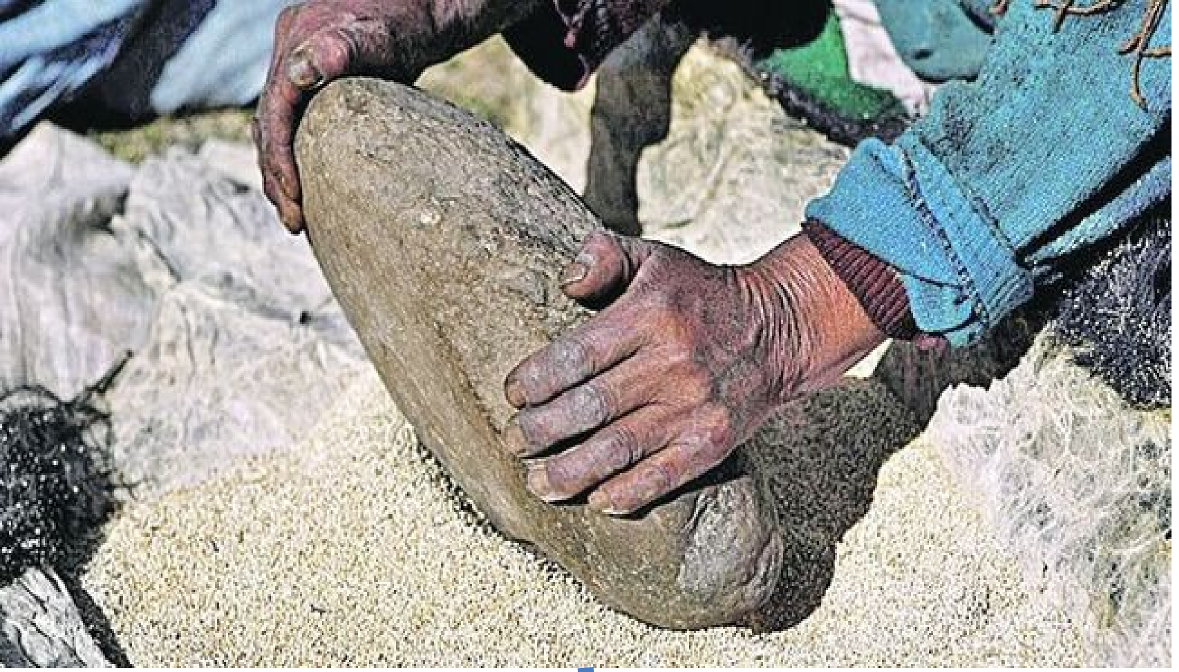
DESAPONICATION / COMPLETE CLEANING OF QUINOA GRAINS

Saponin is a toxic glycoside, present in the pericarp and outer layers of the quinoa grain, which facilitates its elimination. It gives it a *bitter taste* and has *anti-nutritional* properties.

1 / Dry way (scarified) : using the principle of wheat or rice polishers.
First the grain is beaten against rough walls to facilitate the detachment of the shell.
Then, the grain is rubbed against sieves and with each other, in order to separate the nearest layer. Finally, the residues and dust of the saponin are removed.
With heat, pre-roasting the grain and then brushing or scarifying.
Dry methods are inexpensive, simple, and do not cause pollution.

2 / Wet way (using water):
By successive washing of the grain, rubbing it with the hands or with a washing machine to remove the episperm, which is the rough membrane where the saponin is housed.
At the industrial level, this method may have drawbacks if the process is inappropriate and well calibrated : high water use, cost of drying the grain and foaming.

From ARTISANAL DESAPONIFICATION
with STONES



To INDUSTRIAL DESAPONIFICATION
with different MACHINES

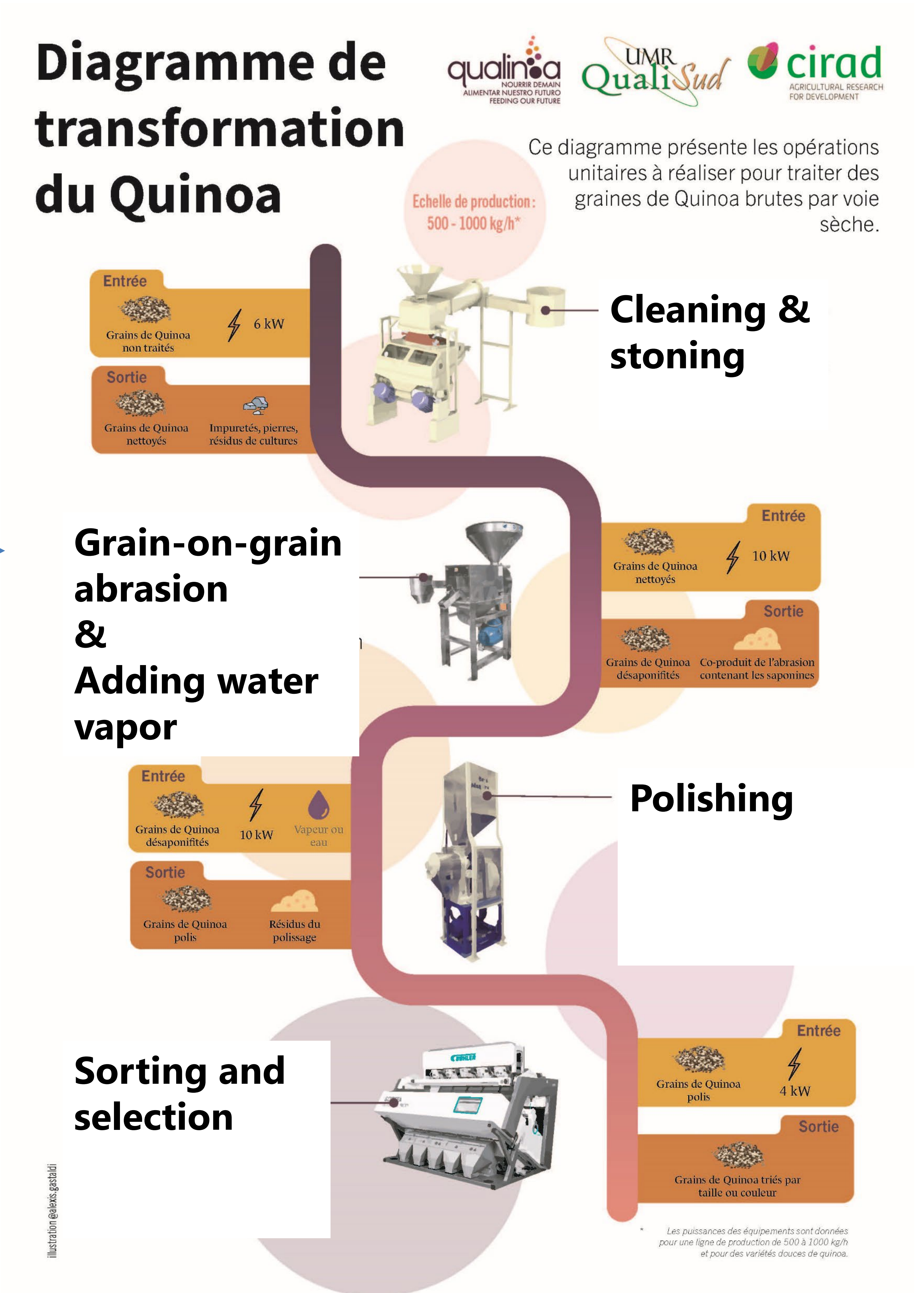
Today

Only very artisanal equipements ***versus*** industrial chains

Low quality of the process ***versus*** high investment

Post-Harvest Diagram

⇒ Didier, Alexis, Michel & Mathieu (Cirad, FR) for the prototype



Designed for small entities 500-1000 kg/h and annual volumes <500 tons

Objectives :

- Reducing the costs for farmers' organizations
- Maintaining the qualities of the final grain

PROCESSING

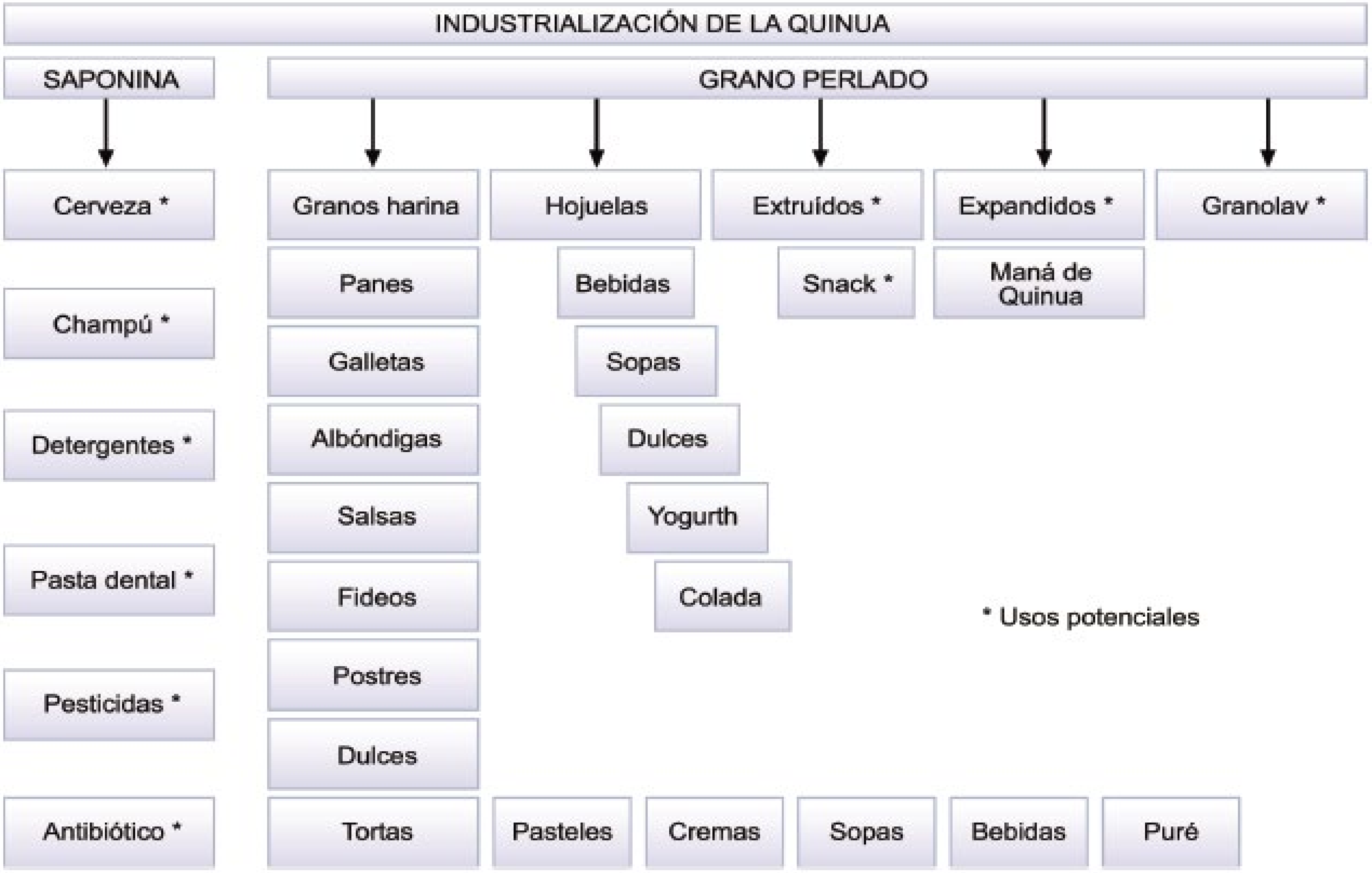
Quinoa can be sold as a grain after post-harvest as "fresh quinoa" (desaponified or not).

__BUT__ it can also be __processed__ for the preparation of various food, cosmetic, pharmaceutical and other products such as: flour, flakes, quinoa milk, cosmetic creams, concentrated saponin, detergents, biocides, oil, dyes, etc.

PRODUCTS OBTAINED BY THE TRANSFORMATION OF QUINOA (Non-exhaustive list)

- Expanded, roasted, pre-cooked grains.
- Flour, Pre-cooked flour: Breads, cookies, cakes, cakes.
- Milk
- Flakes
- Extruded
- Starches
- Dyes: Betalains, Beezzhanthins.
- Saponin, biocides, repellents.
- Concentrated protein
- Pearl
- Sprouts, freeze-dried leaves, pickled panicles.
- Grained: Quinuoto
- Malts and nectars
- Noodle and pasta making
- Sweets, jams, liquors, beer, etc.

PROCESSING


INDUSTRIALIZACIÓN DE LA QUINUA
SAPONINA
GRANO PERLADO
Cerveza *
Champú *
Detergentes *
Pasta dental *
Pesticidas *
Antibiótico *
Granos harina
Panes
Galletas
Albóndigas
Salsas
Fideos
Postres
Dulces
Tortas
Hojuelas
Bebidas
Sopas
Dulces
Yogurth
Colada
Extruídos *
Snack *
Expandidos *
Maná de Quinua
Granolav *
Pasteles
Cremas
Sopas
Bebidas
Puré
* Usos potenciales

Some examples of quinoa based products

Grains

Flour

Pasta

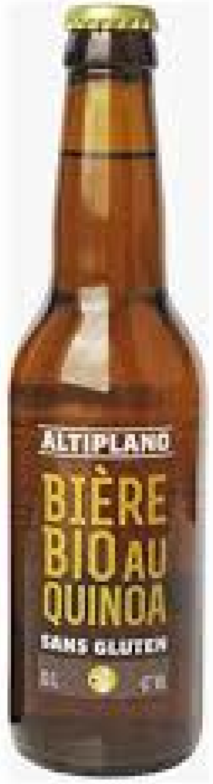
Flakes


Chips



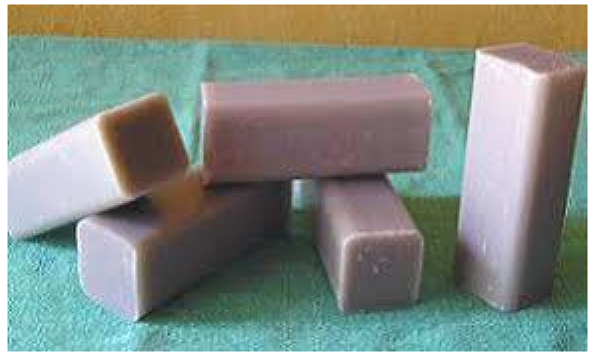
Pigments

Milk



Beer

Prepared Dish

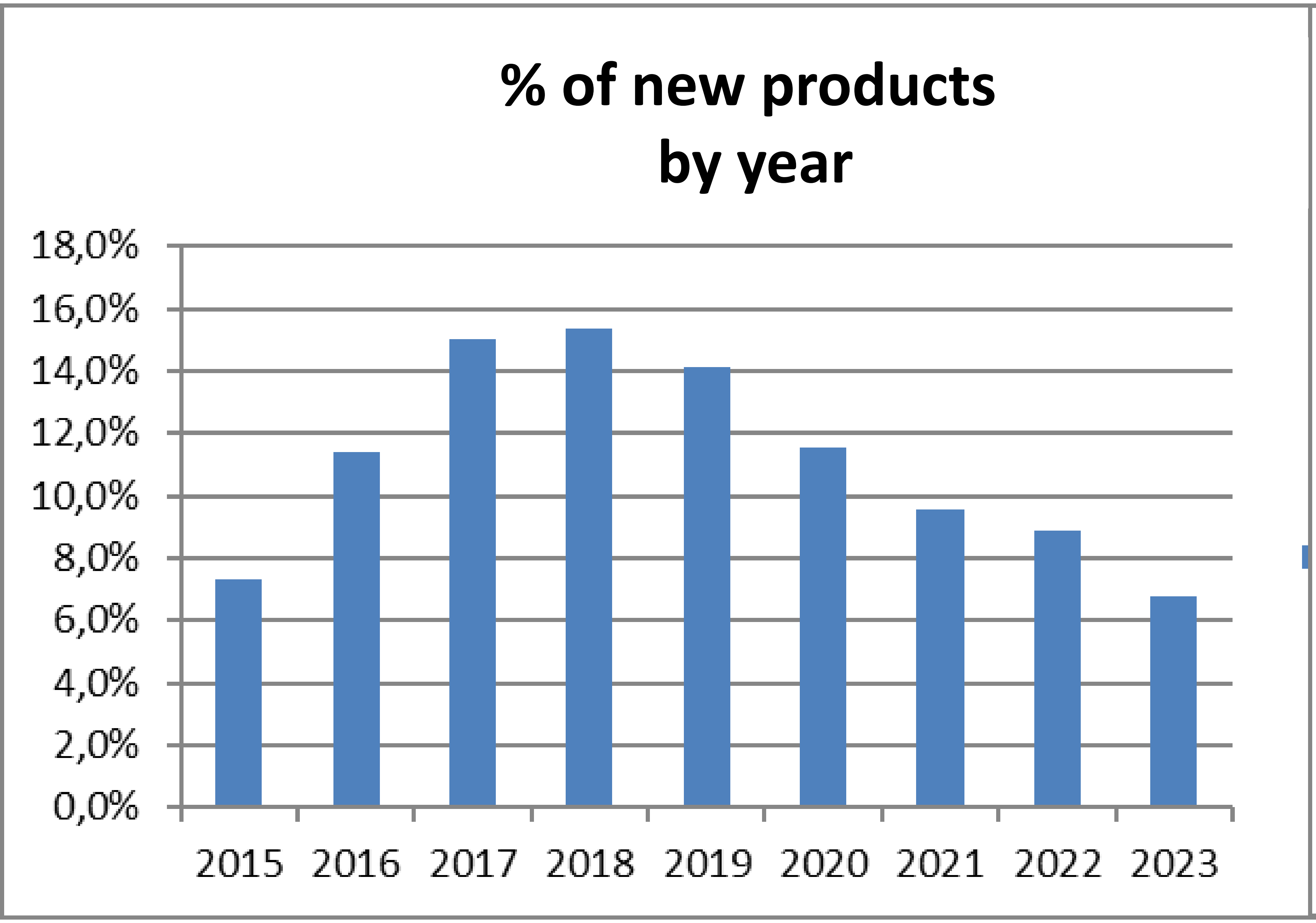

Saponins

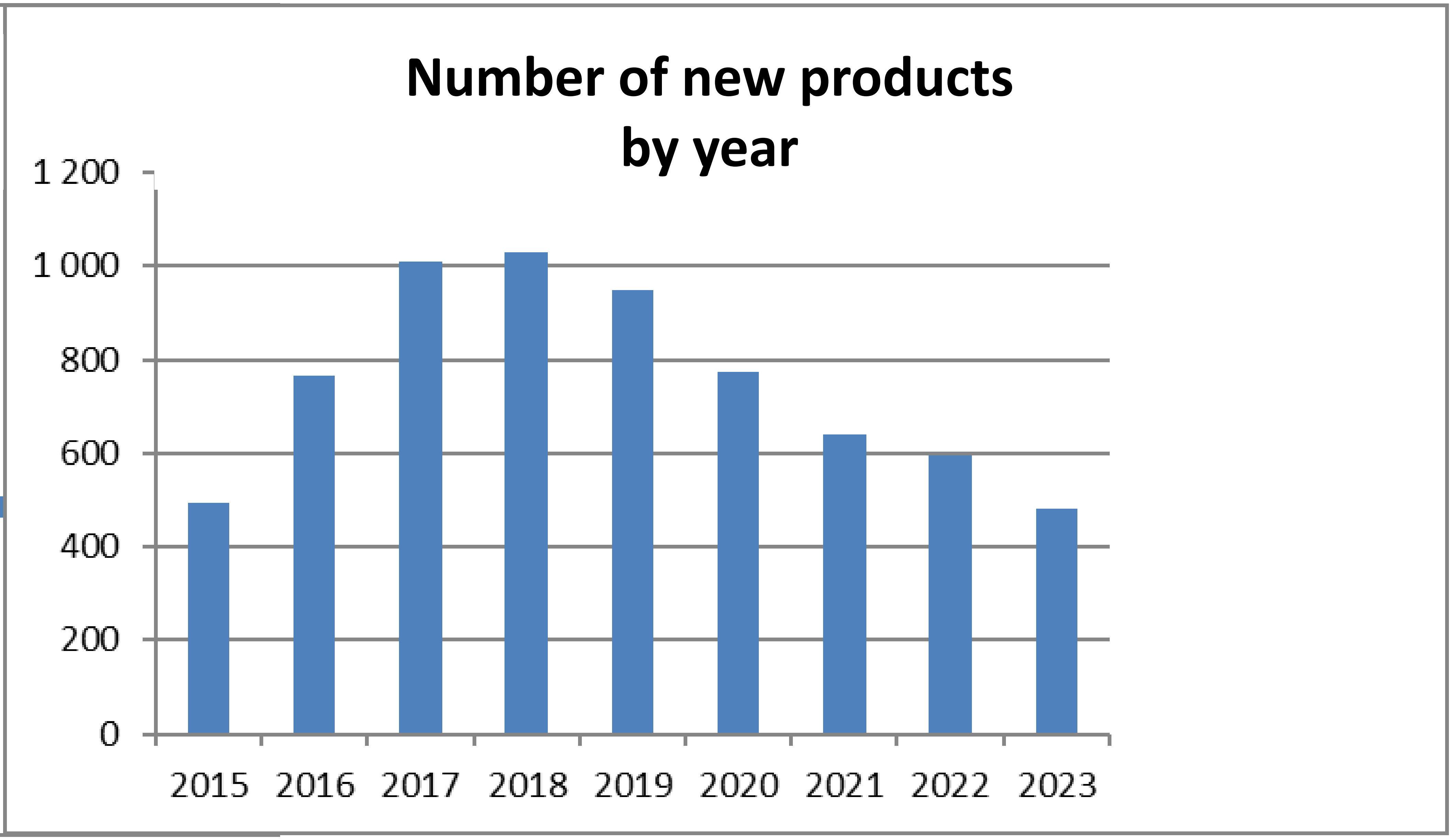
Cosmetics


Bread

Biscuits, and etc.

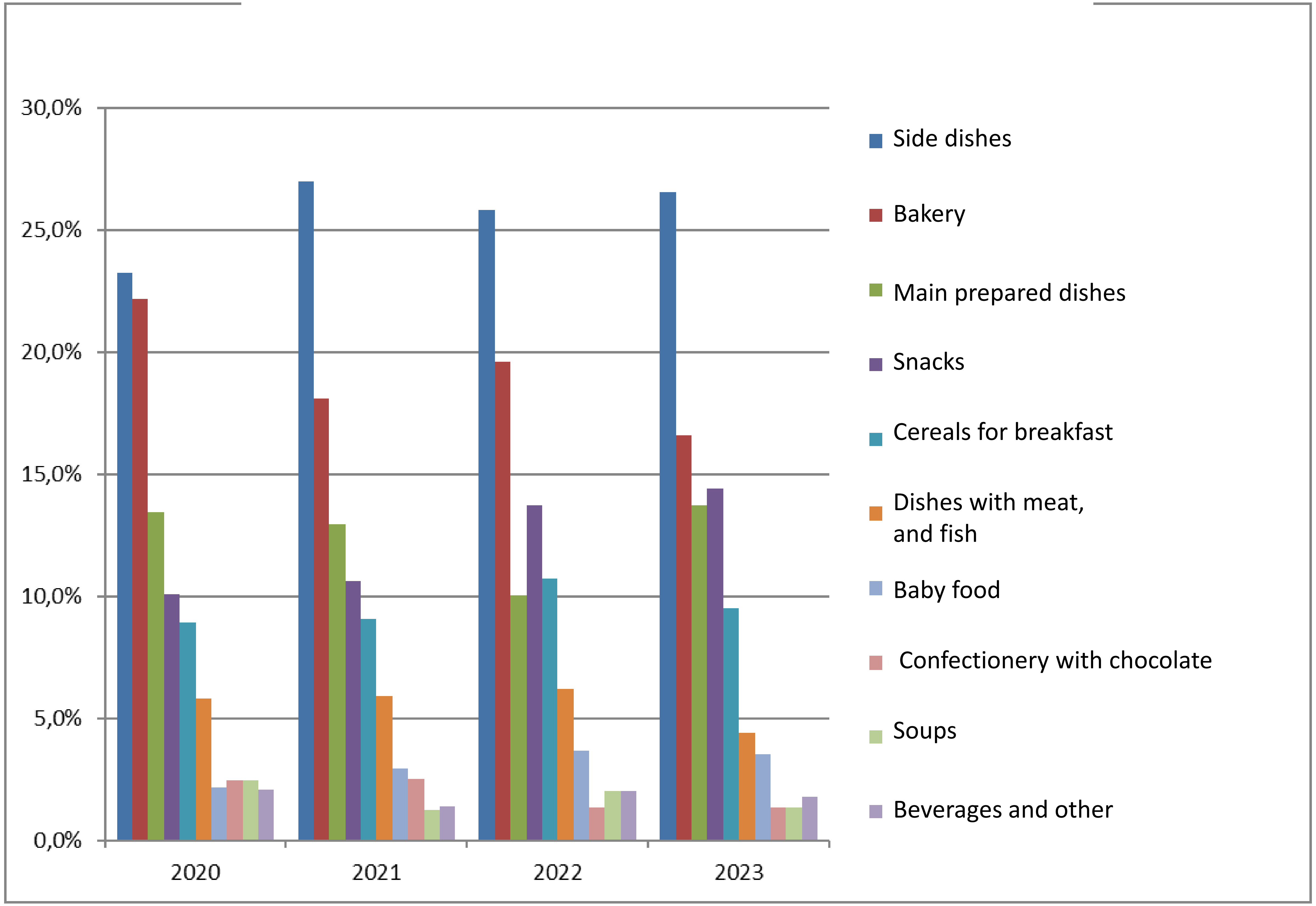
Launching new quinoa products in Europe from 2015 to 2023





We see here that 2018 saw the launch of 1030 quinoa-based products out of a total of 106,850 products entered into the database MINTEL that year, which is very low in terms of % (0.9%).

Categories of new quinoa products launched in Europe from 2020 to 2023




SELECT &GO
salade
Veggie
- BOULGOUR -
quinoa, lentilles
cranberries
Eat Real
QUINOA CHIPS
SOUR CREAM & CHIVE
ΠΑΠΑΔΟΠΟΥΛΟΥ
Cream Crackers
ΠΟΛΥΣΠΟΡΑ
με ΚΙΝΟΑ
fit spo
100% NATURAL
VEGAN
APRICOT+QUINOA
Corn Crake
bio-organic
kruidnoten
petits biscuits aux épices
mini spiced cookies
Jannis
SUPER
Mandolatakia
Φιστίκι
Καρύδα
Κινόα
Yooji
MON BÂTONNET À
MANGER MAIN
Les Galettes Boulgour & Quinoa
TOMATES
& PAPRIKA DOUX
Céréal
BIO
SOURCE DE PROTÉINES
& DE FIBRES
FABRIQUÉ
EN FRANCE
TEVA DELI
BBQ
Alka® Greens
BASISCHE VOEDINGSEXTRACTEN
Zuur-base in balans!
Langham's
CUISINE
Beef Burger
Dog Treats
dobra
kaloria
ZIOMKI
ANANAS & KOKOS
HEJ
NATURAL
BITE
Roasted
NUTS
BIO
BRETZELS D'EPEAUTRE
QUINOA & HUILE D'OLIVE
150g

II/ Focusing on the two objectives of the IYQ in 2013

Genetic Diversity

Environmental conditions

Farmers practices

High Nutritional Value

Post-Harvest Processes

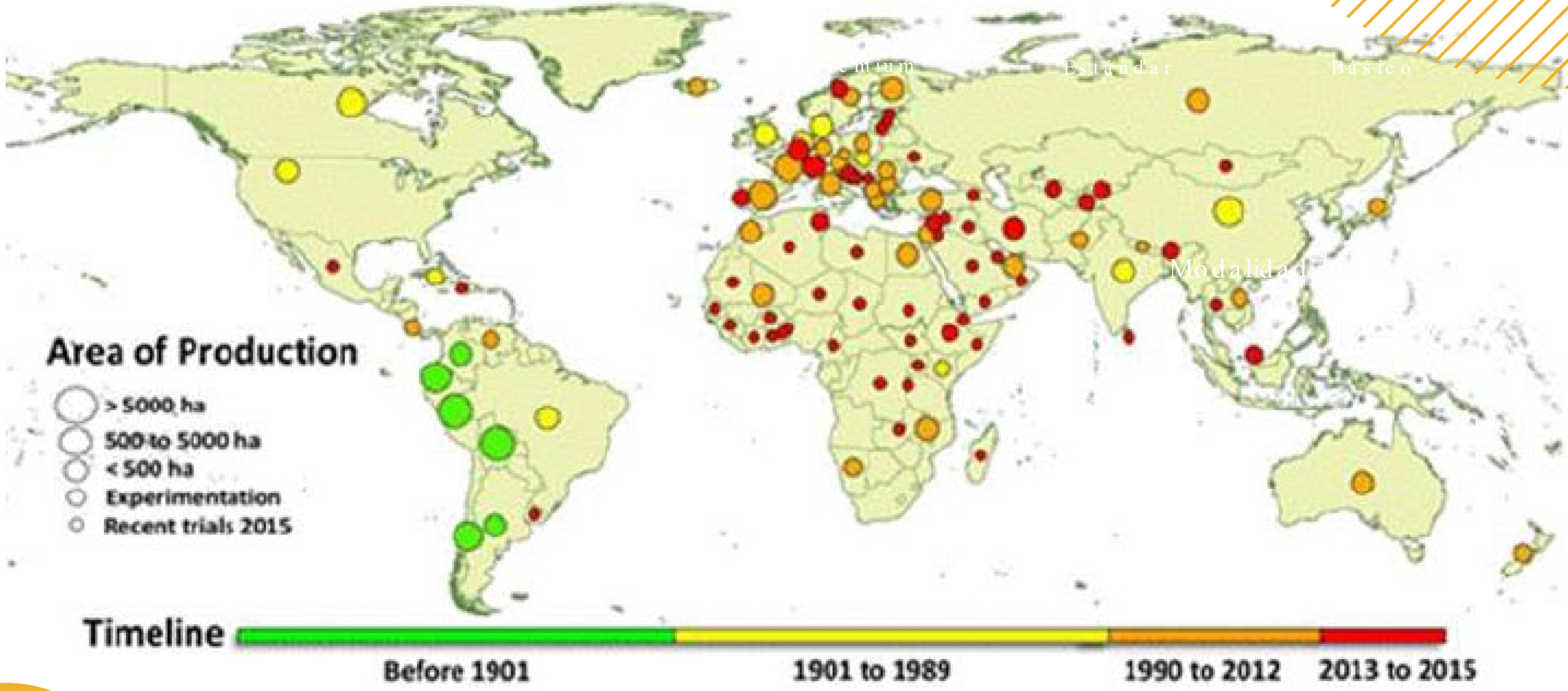
=> What do we really eat?

Background to the recognition of *C. quinoa*

- The Plurinational State of Bolivia has requested FAO to declare 2013 the International Year of Quinoa.
- By resolution 66/221 of 22 December 2011, the United Nations General Assembly proclaimed 2013 as the International Year of Quinoa (IYQ) and the secretariat was assigned to FAO -RLC (Santiago de Chile).

The objective of the IYQ was to draw the world's attention to the role of **biodiversity** and the **nutritional value** of quinoa in food security and poverty eradication, in order to achieve the Millennium Development Goals.

In 2021 (our latest estimate)



Today, quinoa is present in at least 125 countries!

www.gcn -quinoa.org (Alandia et al, 2019)

The new quinoa producers

Small scale farmers with <2ha for diversifying their cropping system (>90%)

Less than 25% with *irrigation*

Organic production (Andes) and more *conventional* production abroad

Commercial varieties selected for *high grain yields*

=> Not necessarily a nutrition-sensitive agriculture





Strong global interest in quinoa

FOR

Fighting malnutrition (only in some cases !)

Reducing poverty (not sure !)

WHAT FOR

Super nutritious foods (not all !) : all EAAs, gluten -free, lots of minerals, vitamins, fiber, quality fats

How (YES)

A highly resilient and adaptable culture

Grows from 0 to over 4000 meters above sea level

Withstands temperatures from -8 °C to +38 °C

Drought tolerant

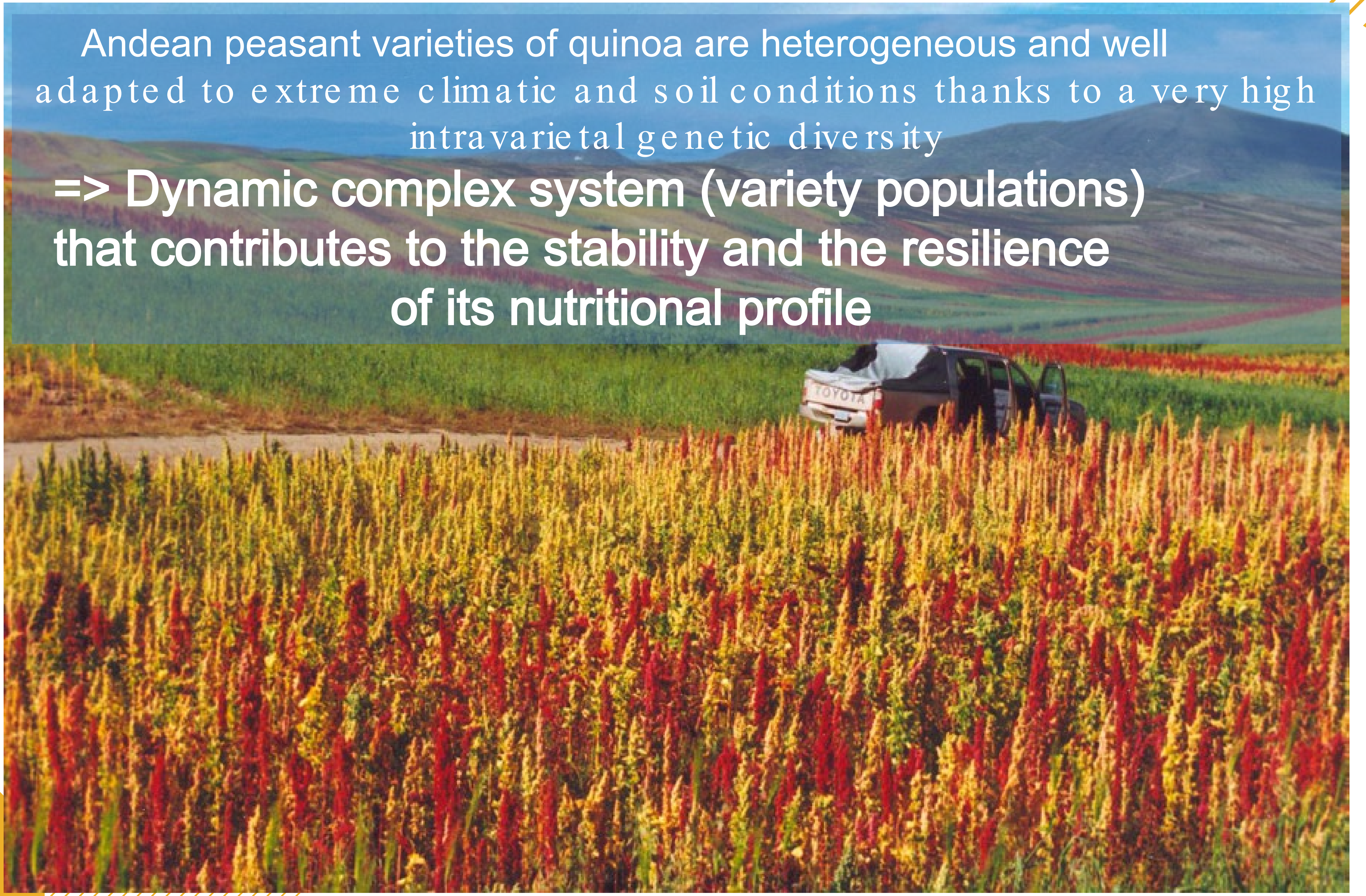
Withstands soil salinity

SO WHAT? …

Great cultivated biodiversity in the Andes

Andean peasant varieties of quinoa are heterogeneous and well adapted to extreme climatic and soil conditions thanks to a very high intravarietal genetic diversity

=> Dynamic complex system (variety populations) that contributes to the stability and the resilience of its nutritional profile



Lake titicaca
4,000 metres
above sea level

1 to 3 regular commercial varieties by country outside the Andes

- Only a very small part of the available genetic diversity is used for the adaptation of quinoa to new environments and for nutritional value.
- Always the same commercial varieties are widely distributed.

Before the IYQ-2013

(in 2012)

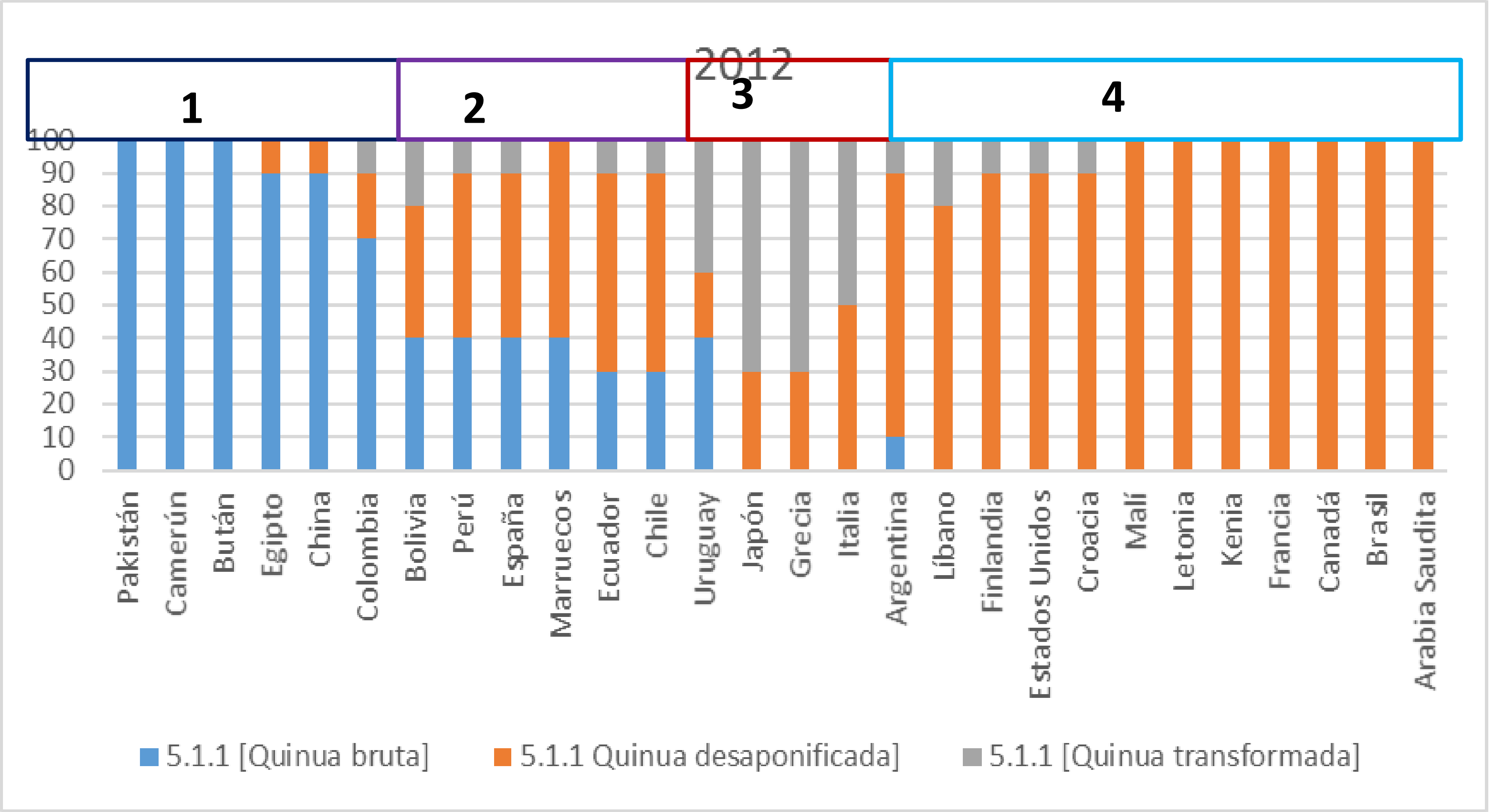
In 2012, four groups can be observed according to the type of quinoa consumed and marketed locally.

1/ Countries where consumption was mostly raw quinoa (***very new producers***)

2/ Raw quinoa and desaponified quinoa (***mainly Andean countries***).

3/ Processed quinoa >70% (***ex. European counries***).

4/ >80% of desaponified quinoa.

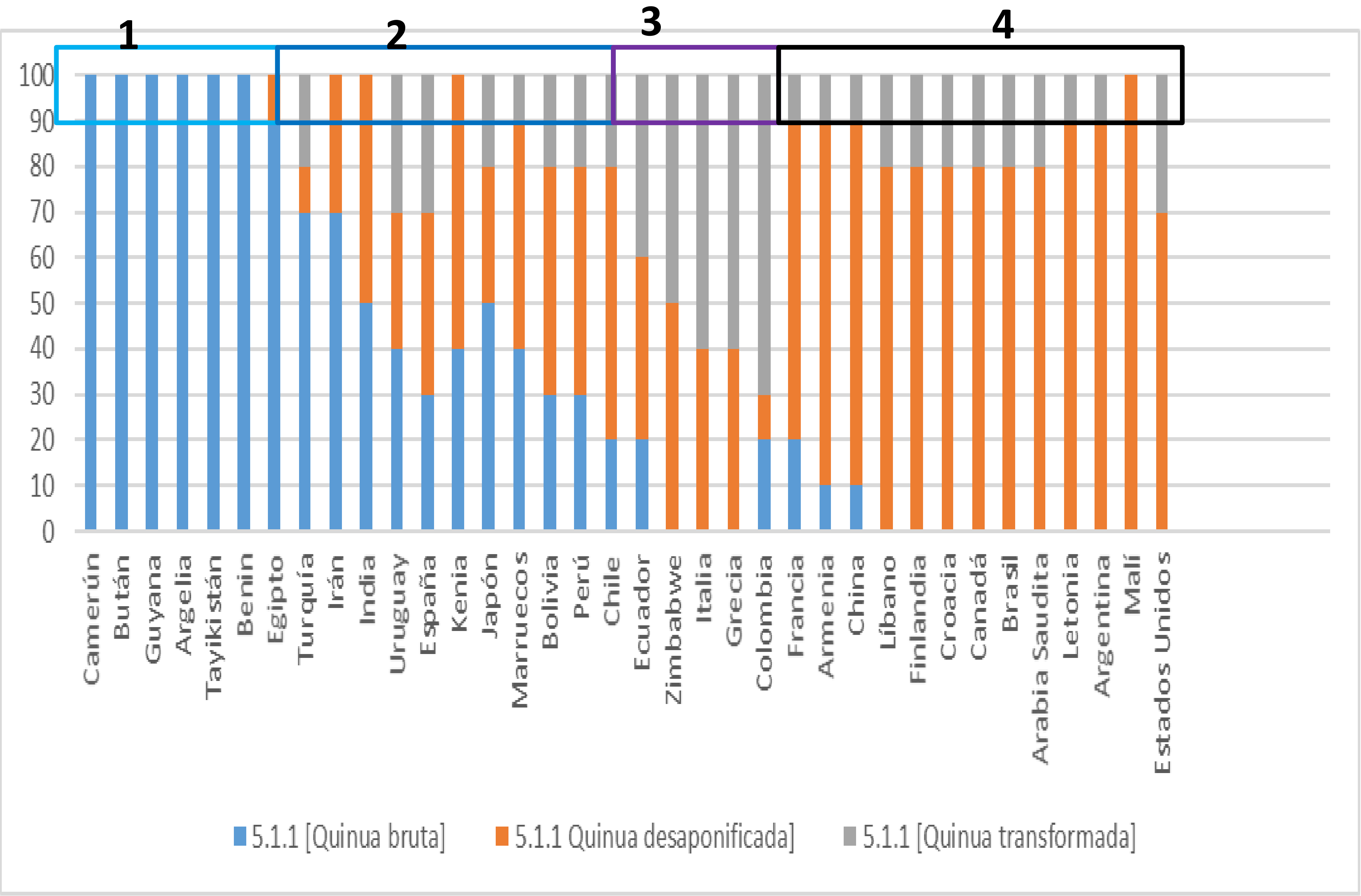


Percentage of local consumption and marketing of raw, desaponified and processed quinoa in the different countries in 2012 (based on 105 surveys and 41 countries)

5 years after the IYQ-2013

(> 2018)

- New countries in **group 1**.
- **Group 2** go progressively to processed quinoa.
- **Group 3** has new countries producers who go directly to processed quinoa.
- Importance of China in **Group 4** with high quantities of desaponified quinoa.



Percentage of local consumption and marketing of raw, dephosphated and processed quinoa in the different countries in 2018 (based on 105 surveys and 41 countries)

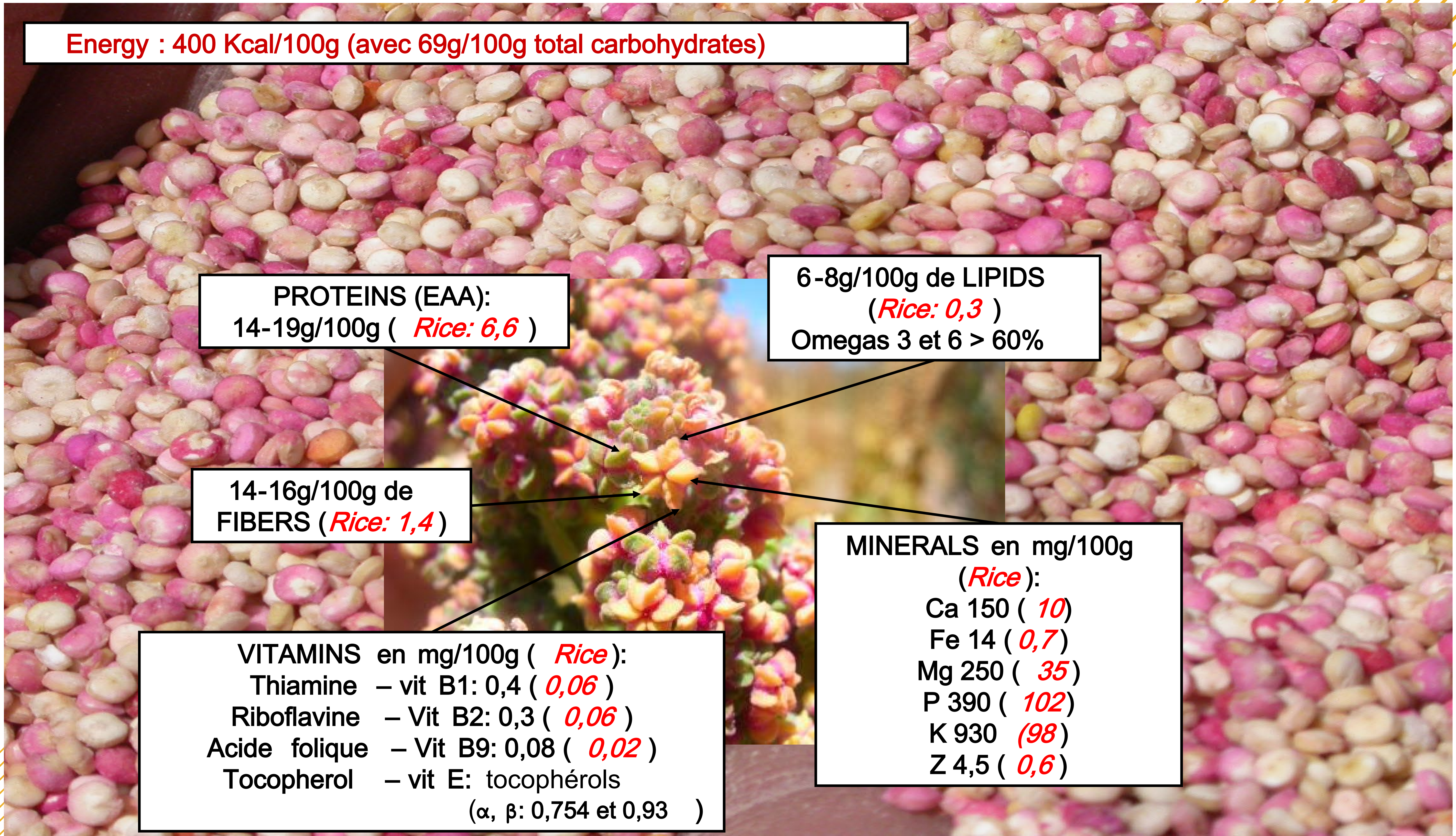
Can the nutritional richness of quinoa serve global food security?

Essential amino acid (EAA) content of quinoa compared to the FAO recommended values (in grams per 100 grams of protein).

	FAO recommendations	**Quinoa**
Isoleucine	3.0	**4.9**
Leucine	6.1	**6.6**
Lysine	4.8	**6.0**
Methionine	2.3	**5.3**
Phenylalanine	4.1	**6.9**
Threonine	2.5	**3.7**
Tryptophan	0.66	**0.9**
Valine	4.0	**4.5**

Adapted from Koziol, 1992.

Promote balanced nutritional content



GOING TO THE
GLUTEN-FREE MARKET

		Rice flour	Wheat flour
		Gluten-free	Gluten containing
Glycemic index		95	85
Carbohydrates (g/100g)		80	78
Lipids (g/100g)		2,2	2,3
Protein (g/100g)		7	8-13
Fibers (g/100g)		1,4	2,5
Nutrients (mg/100g)	**Calcium**	10	50
	Iron	0,7	3,8
	Magnesium	35	170
	Phosphorus	102	467
	Potassium	98	578
	Zinc	0,6	4,7
Vitamins (mg/100g)	**B1**	0,06	0,45 - 0,49
	B2	0,06	0,17
	E	0,05	0,6

Quinoa can be the key

for the

GLUTEN-FREE MARKET

		Quinoa flour	Rice flour	Wheat flour
		Gluten-free	Gluten-free	Gluten containing
Glycemic index		**35**	95	85
Carbohydrates (g/100g)		69	80	78
Lipids (g/100g)		6-8 **Omega 3 & 6 > 60%**	2,2	2,3
Protein (g/100g)		**11-23**	7	8-13
Fibers (g/100g)		**14-16**	1,4	2,5
Nutrients (mg/100g)	**Calcium**	150	10	50
	Iron	14	0,7	3,8
	Magnesium	250	35	170
	Phosphorus	390	102	467
	Potassium	930	98	578
	Zinc	4,5	0,6	4,7
Vitamins (mg/100g)	**B1**	0,4	0,06	0,45 - 0,49
	B2	0,3	0,06	0,17
	E	**2,5**	0,05	0,6

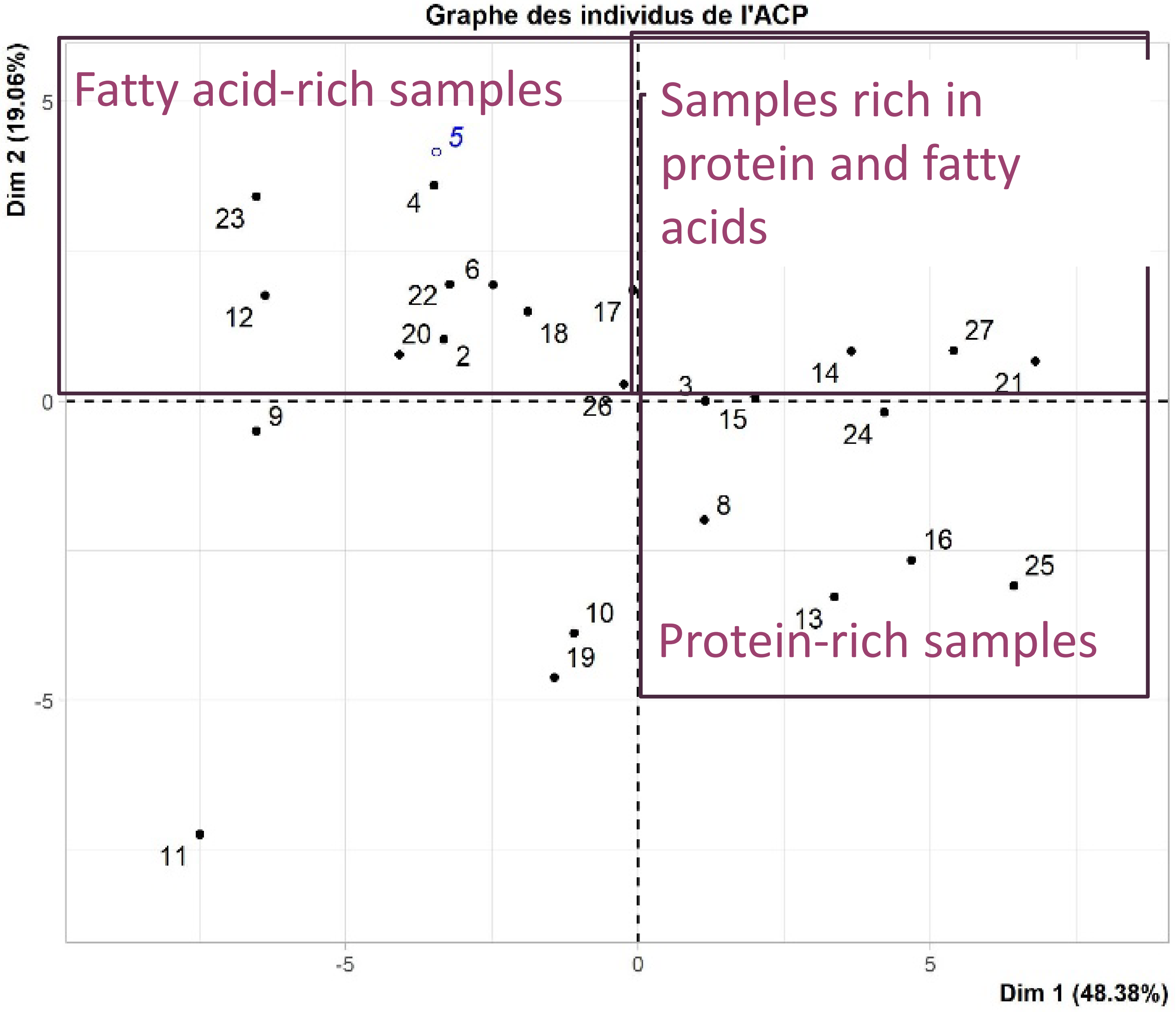
BUT WE NOTE a strong variability in the *average composition* of quinoa grains

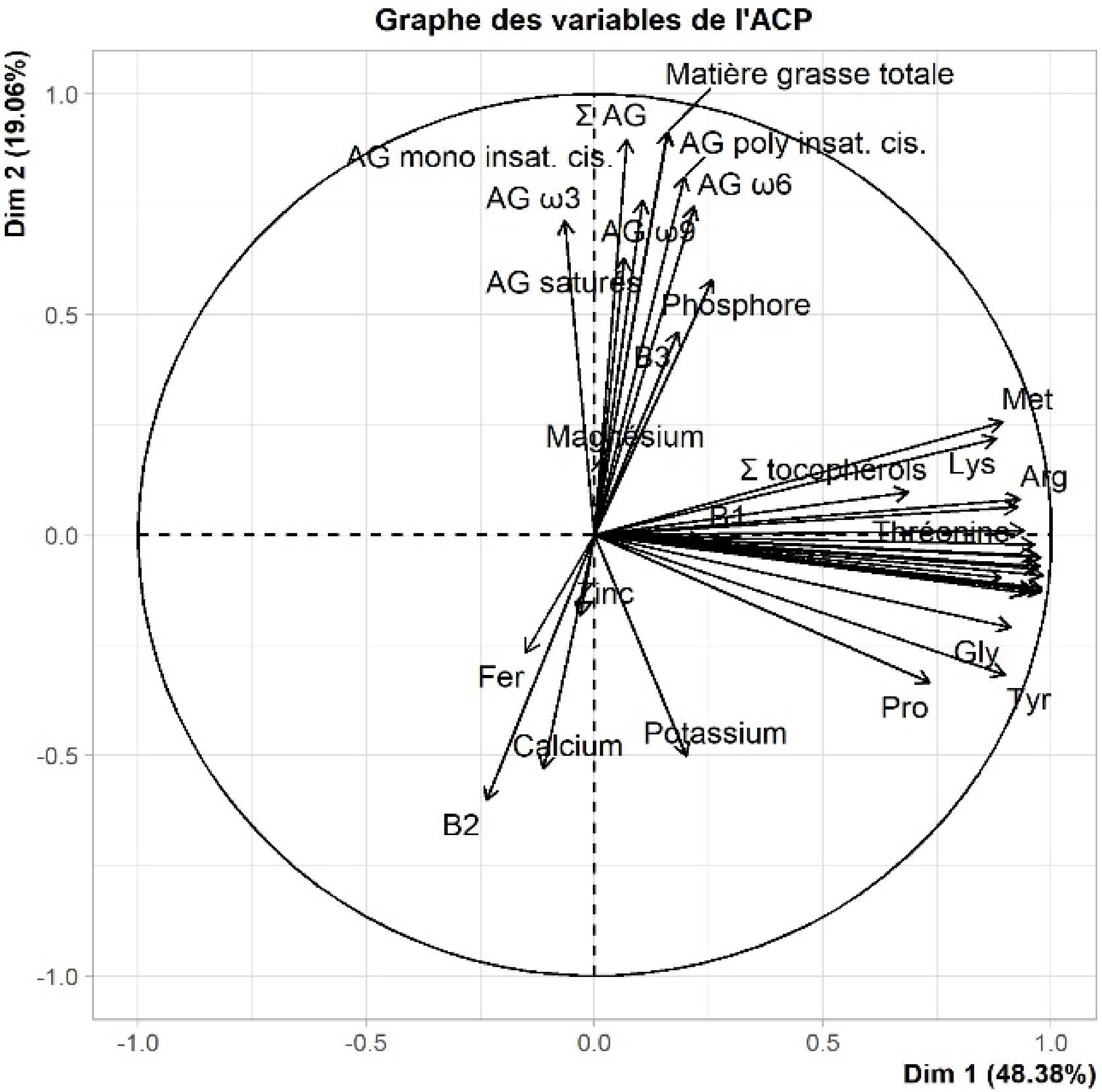
Flours and starches	Starch (% d.b)	Amylose (% of starch)	Proteins (% d.b)	EAA (% d.b)	Lysine (% d.b)	Fat (% d.b)	PUFA (% lipids)	SFA (% of lipids)	Ash (% d.b)	Total dietary fiber (% d.b)	Soluble fiber (% d.b)
Rice	70-85*	17 [1;25]**	6-8	4	0.30	0.5-2.5	25	75	0.15-1.5	5	15
Quinoa Average [Min;Max]	50-65 [32;87]	5-15 [4;26]	12-17 [4;23]	5.8 [4.3;8.2]	0.65 [0.444;1.007]	5-7 [1.8;14.5]	85 [77;92]	12 [10;15]	2.0-4.0 [0.7;6.2]	12 [4;18]	3.0 [0.8;6.1]

From (Abugoch James, 2009; Alvarez-Jubete et al., 2009; Culetu, Susman, et al., 2021; Elgeti et al., 2014; El-Sohaimy & Mehany, 2015; Gallego et al., 2014; Hager et al., 2012; Kozioł, 1992; Lindeboom et al., 2005; Nowak et al., 2016; Repo-Carrasco-Valencia et al., 2010; Schlick & Bubenheim, 1993; Wu et al., 2017)

First results of Amandine CECCALDI (PhD Student at Qualinoa)

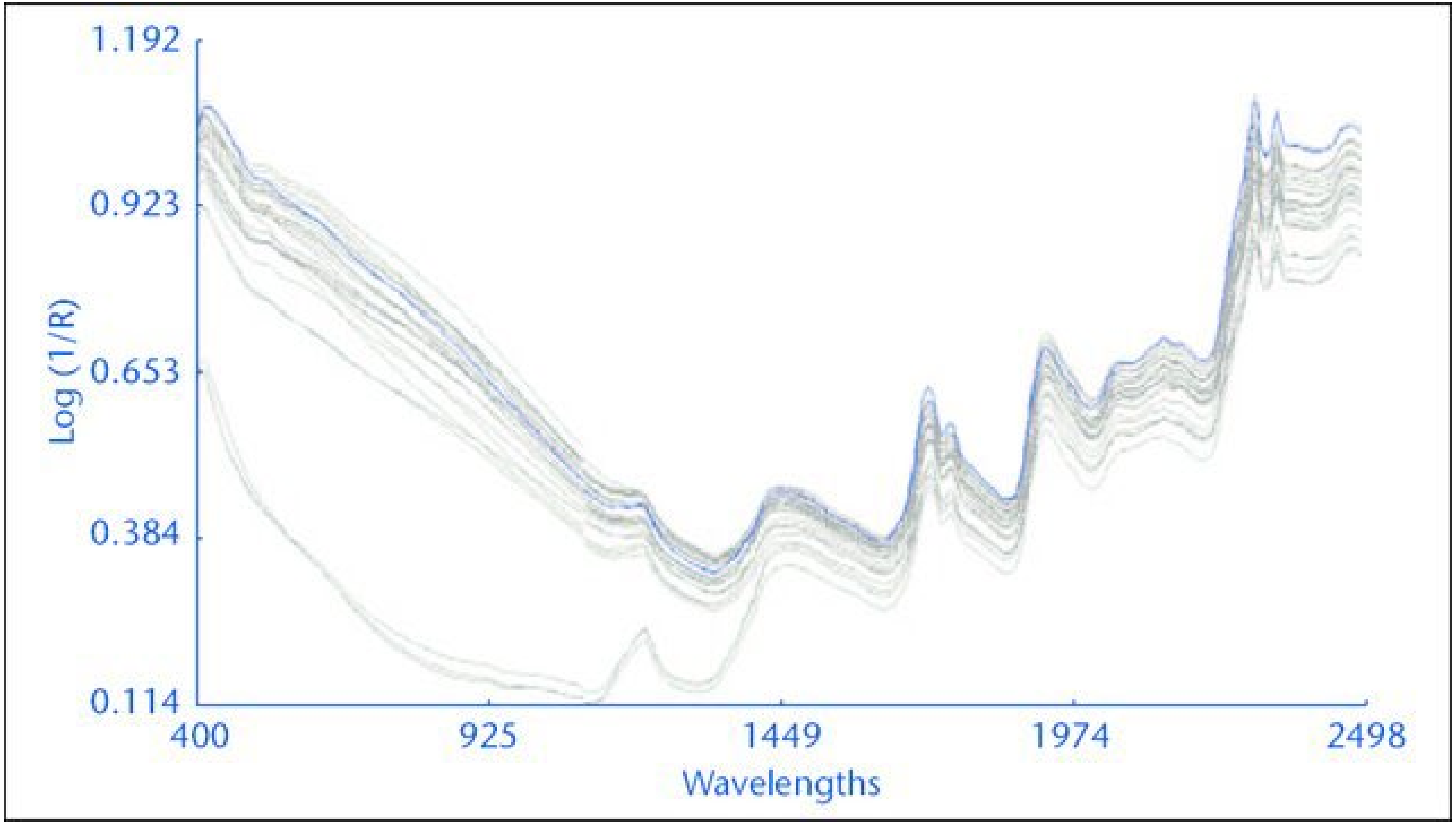
Biochemical characterization of the diversity of quinoa varieties





Next Step: Using the NIRS tool for characterizing quinoa's nutritional variability

=> Example of spectrum family obtained at the NIRS on grains processed into flour



Objective: to determine groups of varieties with similar composition , or not (complementarities), for blends

Quinoa is a healthy product, *between belief and representation*

A product grown by hand in a natural way on the Andean highlands

The average nutritional value of a quinoa grain is the one I have on my plate

?

Changes in Quinoa Nutritional Composition

Environmental issues:
- Temperature
- Precipitations
- Salinity
- Etc.

Farmers' practices:
- Sowing density
- Fertilization
- Pesticides
- Irrigation
- Etc.

Transformation:

Post-harvest operations
Harvesting
Cleaning
Selection, etc.

Agroindustry Foods
Milling
Toasting
Extrusion
Fractionning,
Cooking, etc.

Consumer cooking

Environmental issues:

- Temperature
- Precipitations
- Salinity
- Etc.

Effect of high temperatures on seed oil => lower **oil content** and detrimental effects on the fatty acid composition. These effects included a lower ratio of oleic acid:linoleic acid and larger ω-6 to ω-3 ratios. (Matías, J. et al. (2022). *Frontiers in nutrition)*

Water-limiting environments are generally associated to higher protein and saponins contents, but with **lower yields**. (Matías, J. et al. *Frontiers in Plant Science)*

Salinity induced deep changes in the amino acid composition and in protein profiles as well as in the contents of bioactive molecules.
The responses were differentially induced in the different landraces, providing evidence that **breeding** can further ameliorate the nutritional quality of quinoa. *In some cases, abiotic stress may improve the nutritional properties of quinoa seeds*. (Aloisi, I., et al. (2016) *Frontiers in plant science)*

Farmers' practices:

- Sowing density
- Fertilization
- Pesticides
- Irrigation
- Etc.

The **increase of plant density** significantly decreased weight of 1000-seeds and weight of hectoliter. **Protein** and **ash** concentrations in seeds increased at low planting density, whereas **carbohydrate** concentration decreased. (Eisa S. et al. 2018)

Nitrogen application affected **protein** fractions and **amino acids composition** of quinoa, but the amount of essential amino acids was not changed by nitrogen application. Total proteins of quinoa had high contents of **lysine** (6.3–8.2 g 100 g^{-1} protein) but low contents of **methionine** (1.2–1.8 g 100 g^{-1} protein).

Pesticides and Heavy Metals can be transferred in quinoa grain during maturity stage.

Irrigation systems may play the same role as precipitations for mitigating water scarcity during a dry rainy season and have similar effects as precipitations for nutritional contents.

Transformations

Post-harvest operations

Harvesting → Field losses, impurities, varietal mixtures, moisture

1st and 2nd Cleaning → Wet or dry cleaning, drying or not, losses = f(time),

Selection, etc. → Removal of small grains of minor varieties

Agroindustry Foods

Milling → Dry or wet, heating, grinding fineness, with or without bran

Toasting → Modification of sugars and proteins, loss of vitamins

Extrusion → Vitamin losses and change of state with starch gelatinization

Fractioning, → Loss of benefits of a whole food and use as ingredients in "ultra-processed" products

Cooking, etc. → Losses according to temperature, humidity, duration and storage conditions

Consumer cooking

→ Losses according to temperature, humidity, duration

III/ Gaps and Needs for the future of Quinoa food products

Genotypes (*genetic diversity*) are **only one component** at the entrance of a complex system, and then many parameters can affect the nutritional profile of a quinoa variety of high quality.

Understanding the impact of **each step of the process** is key for determining the **loss of nutritional quality** during all the process of producing quinoa food products.

Depending of the process, we can loss very high quantities of some specific **macro or micro nutrients**.

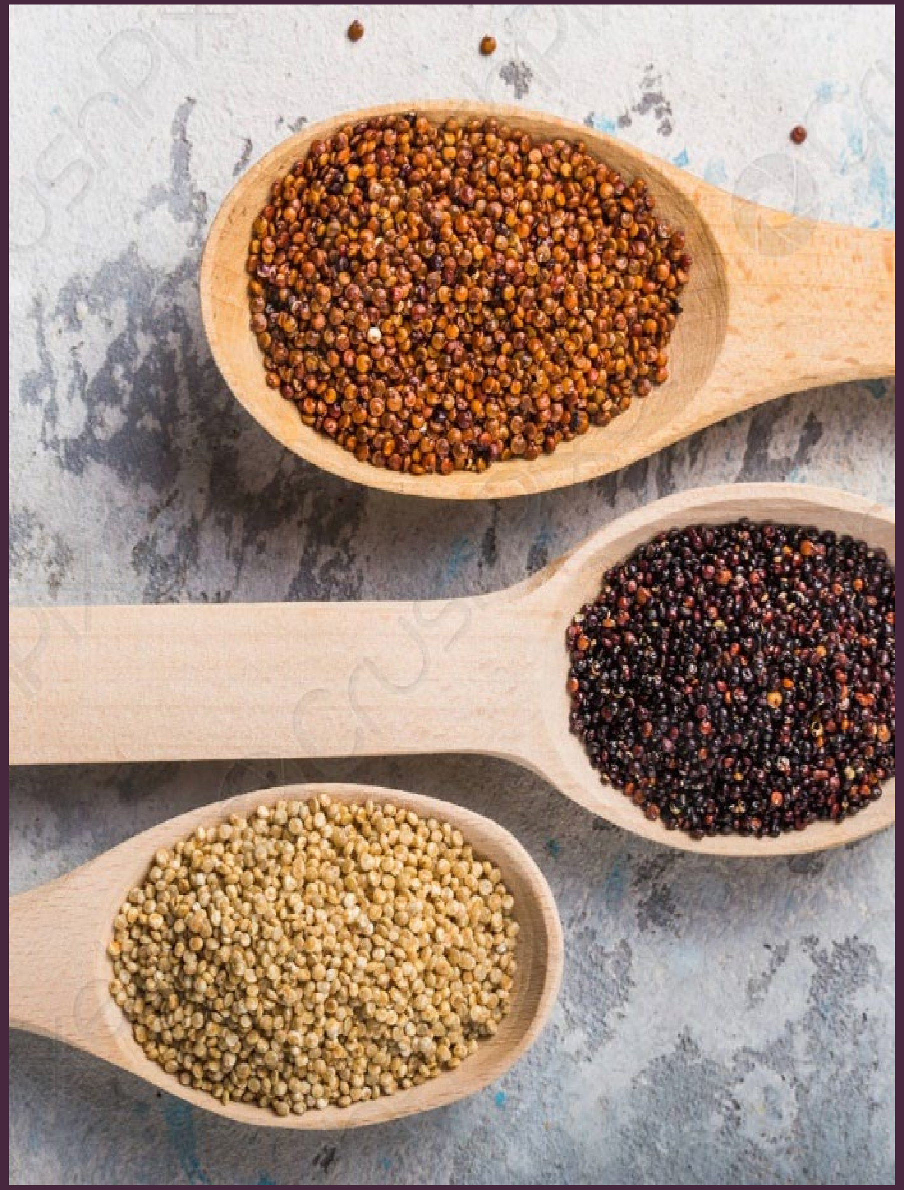
Depending of the destination of the product, we don’t need the same **nutritional traits** and the same **technological traits** (for specific functions).

Examples of Qualinoa R&D activities
with some novel products under development
with my new company Qualinoa

qualinoa
NOURRIR DEMAIN
ALIMENTAR NUESTRO FUTURO
FEEDING OUR FUTURE

DESIGNING GLUTEN-FREE FOODS

- high **nutritional value**
- **quinoa flour blends**



Diversifying the uses of quinoa to help conserve its high biodiversity

TRUE QUINOA BREAD

Convenience

Ready-to-bake mix

Simple to use

Quality

Bread with >50% quinoa

Gluten-Free, high nutritional value

Traceability

Safe & traceable ingredients

No preservatives, organic and committed

A WIDE RANGE OF CONSUMER PROFILES

Health

Clean & safe

Ideal for celiac patients, people with gluten intolerance and allergies

Quality

Whole grain, no preservatives, high nutritional value

Consumers of organic food, vegans, vegetarians, athletes, seniors

OUR QUINOA PRODUCT RANGE

Flagship recipe

Mix Quinoa 64 %
« The Authentic »

Mix Quinoa 50 %
& Buckwheat
« The Local »

Mix Quinoa 55 %
& Hemp
« The Protein-rich »

Mix Quinoa 42 %
Rice & Squash
« The Grainy »

Mix Quinoa > 50%
for GF sourdough
« The Terroir »

FIVE MIXES
Ready to go
to the GF Market

NUTRITIONAL CLAIMS

	The authentic	The local	The protein-rich	The grainy
Fats				
of which saturated fats	Low level	Low level		Low level
of which omega 3	Good Source		Good Source	
of which omega 6	Contains	Contains		Contains
Carbohydrates				
of which sugar	Low level	Low level		Low level
Protein		Good Source	Good Source	
Fibers	Good Source	Good Source	Good Source	Good Source

Further research

Steam Cooking Test for
Quinoa Gluten-Free Breads

Bread-making test according to the composition of **quinoa starches**

Impacts of **extrusion** and **gelatinization** on bread making and on final product quality

*Optimization **models** for **blending** quinoa varieties*

=> Development of **new protocols** for measuring the nutritional value of quinoa focused on **key parameters** of its high nutritional value depending of the **destination**

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Thank You!

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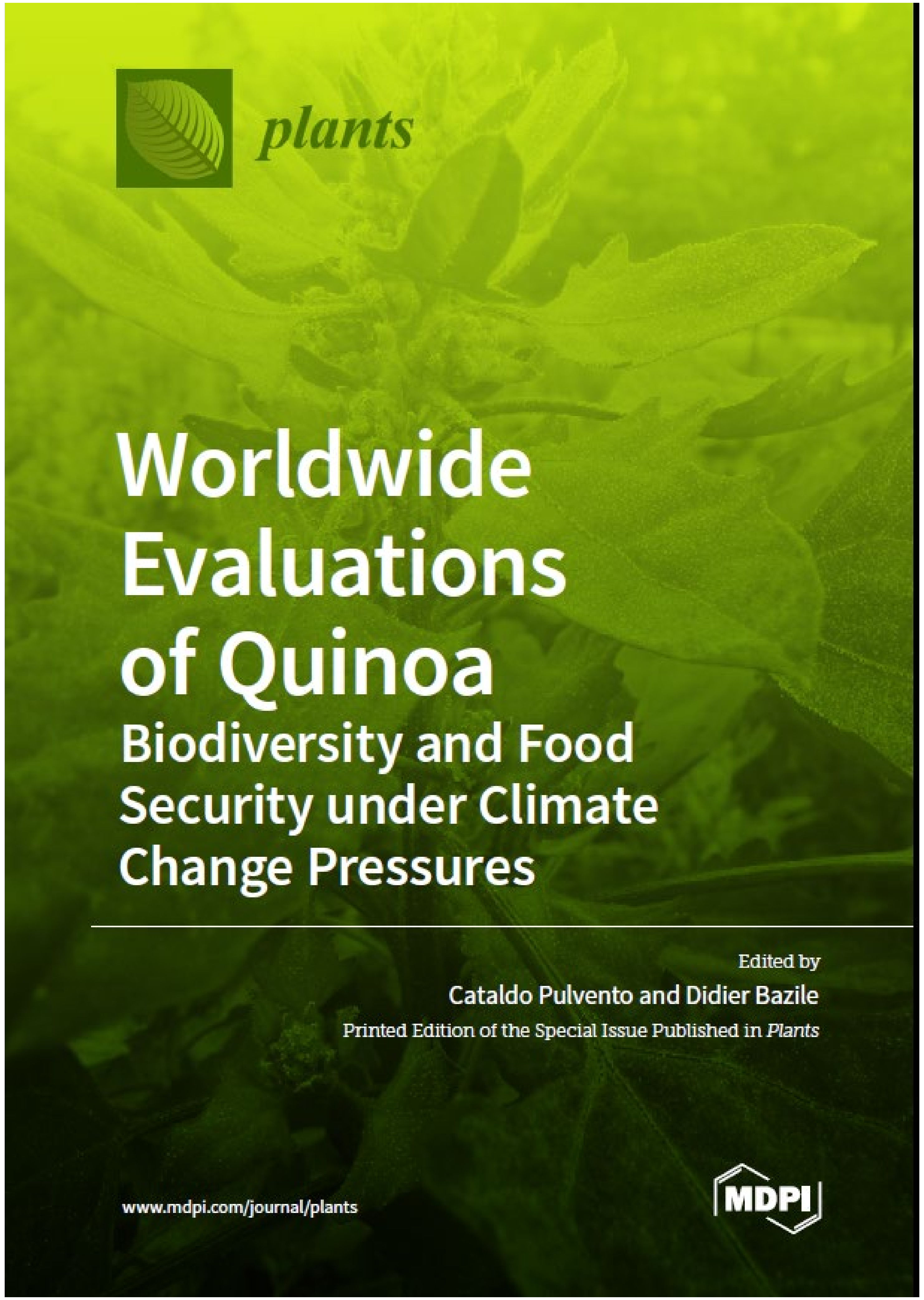

This volume collates the main recent developments from studies on quinoa (*Chenopodium quinoa* Willd.) worldwide.
The most important studies focused on the study of the main agronomic practices, ecophysiological traits, genetics, and post-harvest aspects of quinoa.
The result of the most recent pieces of research carried out by scientists from international universities and research centers are included.

Published Papers in the first volume : 29 papers

Worldwide Evaluations of Quinoa and Amaranth—Biodiversity and Food Security under Climate Change Pressures

Volume II

https://www.mdpi.com/journal/plants/special_issues/SUTQ0S5I5G

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