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Traditional Production, Processing and Quality Attributes of *Ziziphus mauritiana* in Savannah Region of Cameroon

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Authors' contributions

This work was carried out in collaboration between all authors. Authors DS and BP managed the survey and the laboratory analyses of the study. Author PD coordinated the work in the framework of AFTER project and validated the survey protocol. Author NR designed the study, supervised the field work and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: *Jaabi*, the local name of the fruit of *Ziziphus mauritiana* Lam, endemic in the savannah region of Cameroon, is processed into flour and cooked into small round cakes commonly called "*Yaabande*." The present work aimed at understanding the relation between the processing practices and the quality of the product.
Place and Duration of Study: The study was carried out from October 2011 to May 2012, in the savannah regions of Cameroon, the main area of *Jaabi* production.
Methodology: The study was done through: *i)* a survey towards 455 actors representing harvesters, processors, traders and consumers; *ii)* the follow-up of processing operations; and *iii)* physico-chemical analysis of intermediary and end products.
Results: The processing practice, exclusively traditional, is the panacea of women who use steam cooking, sun drying or stifle cooking to bake the cake. The steam cooking method is more popular. The quality attributes of the cake, as perceived by operators and consumers are based mainly on the maturity of *Jaabi* grain and the color and texture of

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the cake. These attributes are particularly dependent on the flour fineness and baking time.

Conclusion: The use of flour with particle size under 125µm, and a steam cooking time of about 10 minutes seem convenient to obtain a cake with light color, firm texture, and to maintain antioxidant activity of the product.

Keywords: Ziziphus mauritiana; particle size; steam cooking time; color; texture; antioxidant activity.

1. INTRODUCTION

Jaabi is, in Cameroon, the local name of the fruit of jujube tree (*Ziziphus mauritiana*), a wild tree, largely spread in the savannah region of the country. The fruit, a round drupe of 2.5 – 6 cm diameter, made of a fleshy pulp surrounding a kernel, is harvested dry and mainly consumed as side-dish. Three varieties of the fruit have been identified in the savannah region of Cameroon: *Z. mauritiana*, *Z. spina-christi*, *Z. mucronata* [1]. *Z. mauritiana* is the variety used in consumption and processing. Its pulp is also pounded into flour which is then processed into a local cake called "*Yaabande*", through pounding, molding and baking using steam cooking, sun drying or stifle cooking. Steam cooking is the most popular baking method. The processing of the fruit into *Yaabande* represents a form of conservation of the product which is consumed throughout the dry season, and even thereafter.

Though *Ziziphus* is spread in savannah regions of Africa, its fruit has not attracted significant scientific interest. It is then one of the underutilized plant species which has not received any benefit in terms of control of the cropping system or development for markets, contrary to the Asian practices where the *Ziziphus* fruit is valorized in different foods and pharmaceutical products, with market, technology and quality development [2]. Out of information provided by Noyé [3] on *Yaabande*, no scientific study exists on *Jaabi*. It is, in fact, evident that understanding the local production and processing systems of *jaabi*, in relation with its characteristics and quality, constitutes one of the main steps to fulfill, in order to set up technology and market spinoff of the product.

In this respect, the present study integrates a survey of traditional *Jaabi* production and processing, and characterization of quality attributes of products in relation with some main processing operations, the expected outcome being to rise up coherent scientific questions for market improvement of the *Jaabi* system.

The theoretical approach of the study involves four complementary steps: *i)* a technological and socio-economic diagnosis of the system (production, processing, trading and consumption); *ii)* a quality assessment of raw, intermediary and end product, in order to determine main quality attributes of products; *iii)* physico-chemical assessment of the products in relation with quality attributes defined in the second step; *iv)* from the results and interactions between steps 2 and 3, innovation hypotheses are drawn for the improvement of the *jaabi* system. This theoretical approach is represented on Fig. 1.

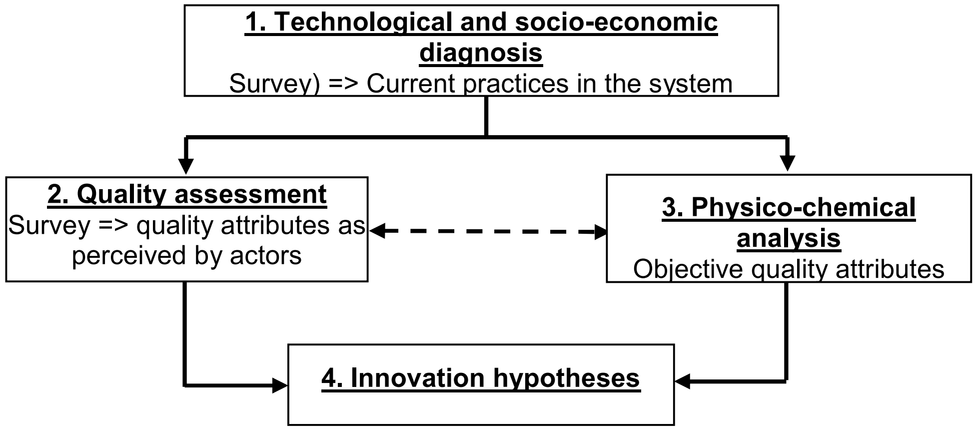

Fig. 1. Theoretical approach for the study of the system

2. MATERIALS AND METHODS

2.1 Survey Methodology

The survey covered the savannah region of Cameroon, which is the principal area of production and consumption of *Jaabi*. It was conducted from October 2011 to May 2012, the main period of harvesting and processing of *Jaabi* in the region. 24 villages and 5 cities were visited. 455 actors randomly selected and representing 178 producers, 32 processors, 95 traders and 150 consumers, were selected according to Dagnelie [4, 5], and interviewed, through a questionnaire, on harvesting practices, processing technologies, and marketing and consumption systems. They had also to provide information on their appreciation of the product at each step of the *Jaabi* chain. In addition, working practices of producers and processors were observed and analyzed.

The collected data were recorded and analyzed using Sphinx Plus^2 V.5 package.

2.2 Processing Analysis

From the observation of processing practices, a flow diagram of the processing was drawn and samples, from a representative processor, were collected at the main processing steps for laboratory analysis.

In addition, the process was replicated in the laboratory, in order to study processing limits. In this respect, *Jaabi* grains obtained from local market were processed into *Yaabande* using steam cooking, in conformity with the processors practices, that is using the same material as in the processor workshop, excepted the fact that a variation was introduced in the fineness of flour, through sieving at different particle size (Ø<125µm; 125<Ø<250µm; 250<Ø<500µm; Ø>500µm and raw flour). Baking was undergone by arranging baking tins containing molded flour in monolayer in the steam cooking pot (Fig. 2), different cooking time (0, 5, 8, 11, 14, 17, 20 minutes) were applied, and electric plate was used as source of energy.

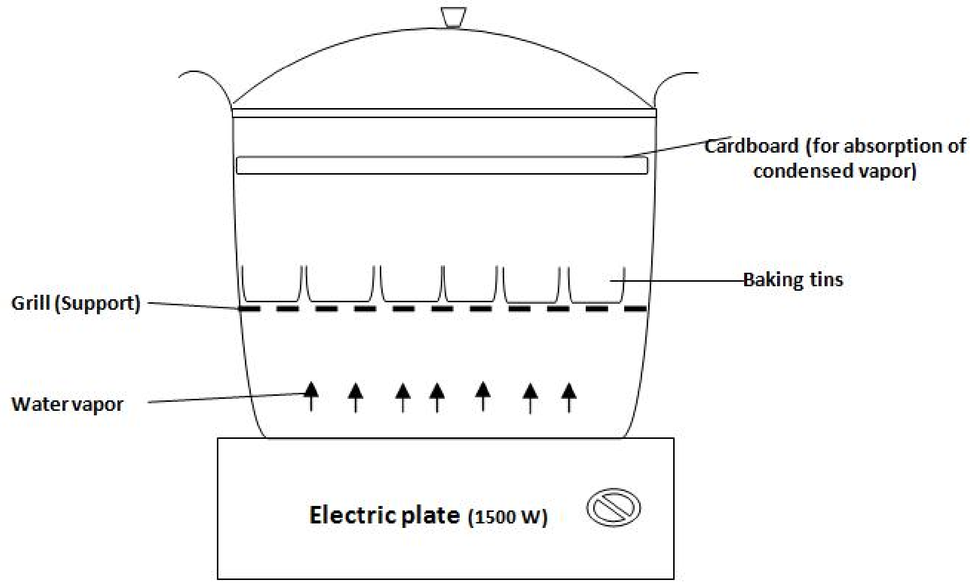

Fig. 2. Steam cooking mounting block

2.3 Physico-Chemical Analysis of Products

Particle size of the raw *Jaabi* flour was measured using vibrating siever (Endecotts Minor - 1332-06). The same material was used for the fractionation of the flour in different particle sizes.

Chemical composition of flours was analyzed for protein [6], soluble sugar [7], pectin [8]. The texture of the *Yaabande* cake was measured using LFRA Texture Analyzer (Brookfield) which measures the force needed by a needle to penetrate the cake [9]. Color parameters of cakes were analyzed using Lovibond RT100 Color Measurement Kit 172 V 2, 28 on the basis of L*, a* and b* values [10]. Antioxidant activity of flour and cakes was measured using DPPH (2, 2-diphenyl-1- picrylhydrazyl) method [11].

All measurements were undergone in triplicate and the results averaged as mean ± standard deviation. Data obtained were subjected to analysis of variance to evaluate the effect of different factors on the response. Least Significant Difference (LSD) test was used to classify these factors when there was a significant difference.

3. RESULTS AND DISCUSSION

3.1 The *Jaabi* Production and Processing System

3.1.1 Actors of the *Jaabi* chain

Though males and females are almost equally involved in harvesting, trading and consumption, the processing activity is carried on exclusively by women (Table 1), certainly because of the technical expertise of women in cooking practices. Meanwhile, since the processing activities are undergone using kitchen materials, it could be admitted that exclusive involvement of women in the processing practices is also cultural, since the processing of *Jaabi* can be considered as domestic activity. In spite of the fact that women are implicated in the other activities of the chain, their productivity in those activities is very low compared to men. In fact, in harvesting, women harvest about 9 bowls of 20 liters of grain per month, while men harvest, in the same time, 5 bags of 100kg. Such difference is also observed in trading activity. Male traders act mainly as whole sellers of grains conditioned in bags of 100kg, a mean of 11 bags been sold par month. Women use mainly cups of about 1kg to retail *Jaabi* grain on market, with an average of 58 cups sold per month.

Table 1. Gender repartition of actors per category of activity

category of activity	Male (%)	Female (%)
Harvesters	57	43
Processors	0	100
Traders	40	60
Consumers	61	39

3.1.2 Harvesting and processing practices

Jaabi fruit is harvested by field collection of mature and dry grains fallen from jujube trees. The harvesting activity of *Jaabi* takes place between November and January, which correspond to the dry season in the region. During this season, the *Jaabi* grains fallen from jujube trees are quite dry and can be easily collected. Harvesting is undergone preferably by collecting dry fruits fallen on the ground or by shaking the tree, or also by sweeping around the tree; the latter practice is done particularly by women. Whatever the collection practice, it is followed by sorting of grains. The average daily time dedicated to these practices is approximately 2 hours, 2.5 hours and 1 hour, respectively for field collection, tree shaking and sweeping. This indicates that the harvesting activity is coupled to other farm activities during the day. In fact, harvesting is undergone, either in the morning or in the afternoon, but neither the whole day.

Processing of *Jaabi* grains into *Yaabande* goes through pounding of grains to obtain flour, which is molded and cooked (Fig. 3). The main operations involved are successively: sorting of grains, pounding of clean grains in a mortar to separate the surrounding pulp from the kernel, sieving to obtain fine flour, molding of the flour and cooking of the cake. The variability of the *Yaabande* processing is mainly based on the procedure used to pack and to cook the cake. In general the flour is molded using small calabash or wrapped in vegetal leaves. The cooking of molded or wrapped samples is either Steam cooking, stifle cooking or sun drying. Steam cooking is the major practice encountered in the region. Depending on the quantity of *Jaabi* processed, and considering the time for the preparation of cooking tools (preparation of calabash for molding, preparation of cooking pot, boiling of water for steam cooking, etc.) the production of Yaabande cake is undergone in 1 to 4 hours, with a production yield of 40-70 g of *Jaabi* grains for a piece of *Yaabande* cake. Pounding represents the time consuming and painful stage of the process, with significant impact on the quality and acceptability of the end product.

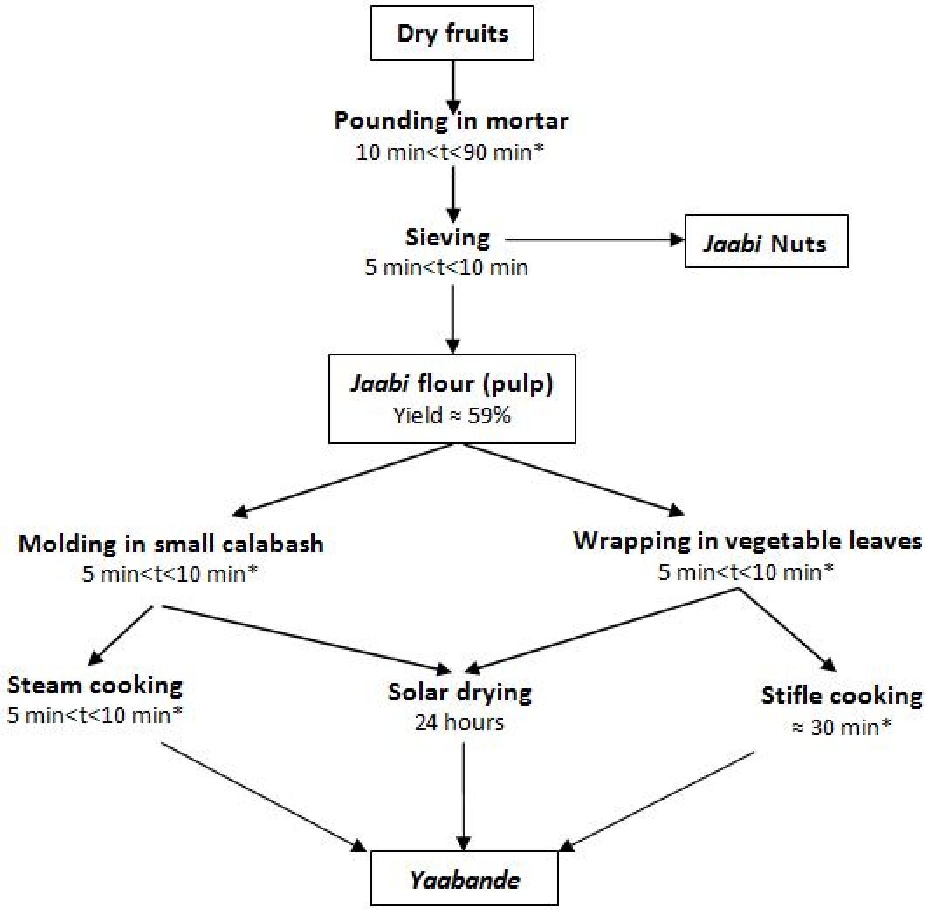

Fig. 3. Process diagram of *Jaabi* processing into *Yaabande*

** The values are the minimum for about 1.5 kg of grains (minimum quantity processed)*

3.1.3 Quality attributes of the *Jaabi* processing chain

Principal Component Analysis (PCA) of the actors' answers related to quality attributes indicates that *Jaabi* and its processed products are perceived differently as far as the initial product (grain), the flour for *Yaabande* processing and the resulting cake are concerned (Fig. 4). The main quality attribute for harvesting of *Jaabi* grain is its maturity. This attribute includes particularly the brownish, reddish or yellowish color of the grain. The flour earmarked for *Yaabande* processing should have a fine particle size. Though quality attributes for *Jaabi* grain and flour are mainly determined by harvesters and processors, those of *Yaabande* cake include also the perception of consumers. In this respect, both actors appreciate *Yaabande* cake particularly through its color (chocolate like), its compact texture (firmness, density, homogeneity) and its sweet taste. In addition, the hygienic aspect (cleanliness) of the products (grain and cake) appears as a marketable attribute.

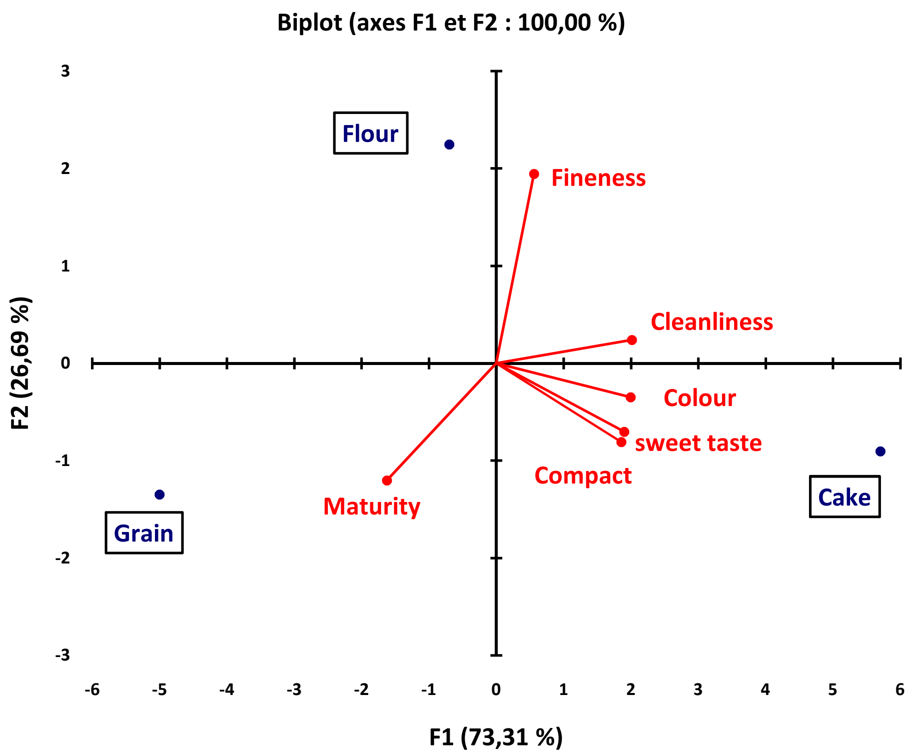

Fig. 4. Quality attributes of *Jaabi* grain and processed products as perceived by operators and consumers

3.2 Relation between Processing Practices and Quality: Innovation Hypotheses

Relating the above quality attributes to the operations involved in the *Jaabi* processing chain, it appears that the main technological steps building the quality of the processed products are flour production (pounding and sieving) and cooking. These two steps have significant effect on the definition of the quality of end product as shown on Fig. 5, presenting the quality constraints of *Jaabi* processing chain in the case of *Yaabande* processing through steam cooking.

From the starting point, the processing activity appears relatively hard, regarding the energy needed for the pounding of *Jaabi* grain for flour production. The main effect of this difficulty lies on the flour yield, since the process could not allow the removal of the totality of pulp from the kernel. This is evidenced when the mixture of kernels and flour obtained by pounding is sieved to separate flour. A significant quantity of pulp remains adhere to kernel. That's why women use to repeat twice or thrice the pounding operation on kernel after sieving.

The direct use of flour obtained without additional and controlled sieving may have an impact on the texture of final cake, since its particle size distribution is relatively large (Fig. 6). In addition, the cake texture may also vary regarding the unknown pressure of flour packing in baking tins.

On cooking, baking tins are piled up in the cooking pot and cooked for 5 to 10 minutes after which tins are removed successively from the top. Thus, it should be admitted that all samples do not have the same cooking time, the bottom samples being certainly more cooked than the upper ones. One consequence of the variation of cooking time may be the effect on the biological activity of the cake, particularly its antioxidant activity [1], which may be reduced on long cooking time.

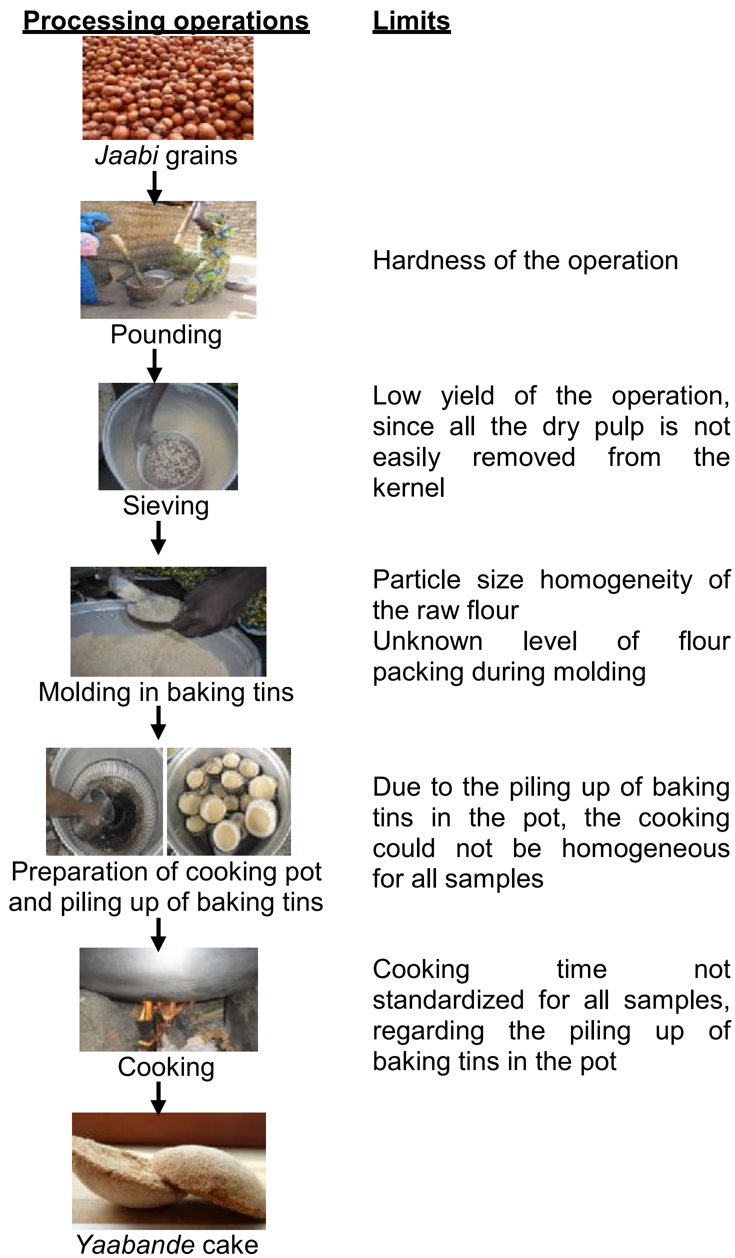

Fig. 5. Quality constraints of *Jaabi* processing chain in the case of *Yaabande* production using steam cooking method

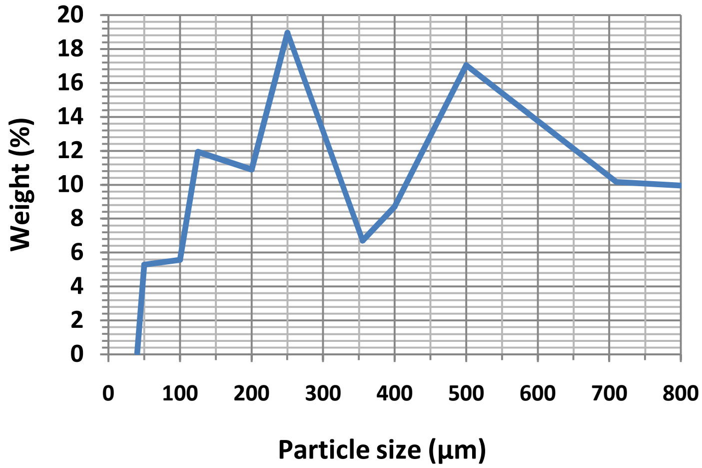

Fig. 6. Particle size distribution of *Jaabi* flour for *Yaabande* processing

The above results reveal two potential factors of variation in the quality of *Yaabande* cakes: the coarse grain flour and the baking time variability of cake samples. It appears, therefore, useful to understand the influence of these factors on the apparent quality of *Yaabande* cakes. The combined effect of flour particle size and cooking time was tested on the texture and on antioxidant activity of *Yaabande* cake.

Some characteristics of the *Jaabi* flour, at different particle size, are shown on Table 2. The chemical composition of the flour is in general constant as a function of particle size, out of the soluble sugar content which increases with the fineness of the flour. This may be attributed to the fact that in very fine flour (Ø<125µm), these free carbohydrates result mainly from hydrolysis of polysaccharides during pounding. The fineness of the flour is characterized by it lightness as shown by the increase of L* value of color parameters with reduction of particle size.

Fig. 7 presents the combined effect of particle size and cooking time on the texture of *Yaabande*. The cake appears firmer when processed with flour of particle size lower than 125µm. This firmness is higher when the cake is cooked for a maximum time of about 12 minutes. This firmness resulting from flour fineness could be attributed to linkage between *Jaabi* carbohydrates and proteins as stated by Jin-Wei Li et al. [12]. These authors showed that proteins and carbohydrates of *Ziziphus* fruit are linked by O-linkage. Since *Jaabi* contains up to 37% (DM basis) free sugar, 2.5% (DM basis) pectin and 0.3% (DM basis) protein (Table 2), this linkage could be possible in the *Yaabande*. Based on this hypothesis and from the variation of firmness observed on Fig. 7, it could be assumed that: the fineness of flour (Ø<125µm) allows more freedom of carbohydrates which could then be easily involved in O-linkage; this linkage may be improved on cooking, particularly during the first 10 minutes of heat treatment, with consequence on the firmness of the cake. Beyond this cooking time, the persistence of heat may have induced pectin degradation, leading to reduction of firmness.

Table 2. Some physico-chemical and biological characteristics of *Jaabi* flour at different particle sizes

Characteristics	Particle size (µm)				
	Raw flour	**Ø>500µm**	**250µm<Ø<500µm**	**125µm<Ø<250µm**	**Ø<125µm**
Chemical composition (%DM)					
Soluble carbohydrates	29,34±0,12[e]	29.99±0.06[d]	32.42±0.48[c]	35.54±0.21[b]	37.74±0.03[a]
Proteins	0.22±0.01[d]	0.23±0.01[d]	0.29±0.01[c]	0.30±0.01[b]	0.33±0.01[a]
Pectin	2.51±0.02[b]	2.72±0.03[a]	2.42±0.01[d]	2.47±0.01[c]	2.49±0.01[bc]
Color parameters					
L*	44.17±1.13[b]	41.00±0.95[c]	41.88±2.71[bc]	53.07±1.32[a]	51.45±1.19[a]
a*	3.47±1.31[cd]	2.40±0.59[d]	3.83±0.50[bc]	5.61±0.44[a]	4.94±0.39[ab]
b*	6.54 ± 0.33[bc]	5.66 ± 0.17[c]	7.70±0.66[b]	14.82±0.99[a]	13.70±0.71[a]
Biological activity					
Antioxidant activity (µg DPPH/100g DM)	22.48±0.36[ab]	17.66±0.16[c]	22.00±1.05[b]	23.21±0.26[a]	21.95±0.68[b]

[a, b, c, ...] *The means in a line, assigned the same superscript letter are not significantly different ($p<0.05$)*

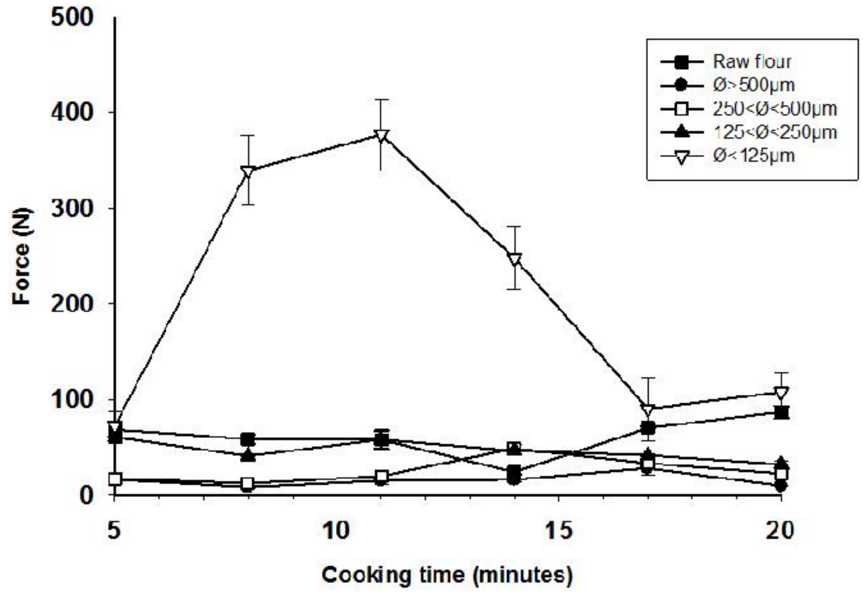

Fig. 7. Combined effect of flour particle size and cooking time on the texture of *Yaabande* cake

Considering the combined effect of particle size and cooking time on the antioxidant activity of *Yaabande* (Fig. 8), the cooking does not significantly affect the antioxidant activity of the product. A slight improvement of this biological activity is even observed on cooking. Meanwhile, it is noted that sample of particle size 250μm<Ø<500μm is at the upper end of antioxidant activity on cooking, while sample of particle size Ø<125μm is at the lower end and even has a tendency to decrease after 5 minutes of cooking. This tendency to decrease is also observed with raw flour and sample of particle size 250μm<Ø<500μm. Different hypotheses may be raised up as tentative explanation of these observations:

i) Kaur and Kapoor [13] assert that polyphenols with an intermediate oxidation state can exhibit higher scavenging activity than non oxidized polyphenols. Since antioxidant activity of *Jaabi* results from its polyphenols content [1], it could be assumed that the increase of antioxidant activity during the first minutes of cooking, may be attributed to oxidation of these polyphenols; the consequence being the increase of the ability of its aromatic hydroxyl group to donate hydrogen atom to a free radical and/or to support unpaired electrons through delocalization around the p-electron system.
ii) The depletion of antioxidant activity after 5 minutes may be attributed either to polyphenolase activity as a consequence of heat and water activity, or to heat degradation of polyphenols with extension of heat treatment. In this case, the higher depletion of antioxidant activity with fine particle size may be attributed to easy exposure of polyphenols of these samples to degradation factors (heat and/or enzyme). But since depletion is of short extent, it could be assumed that the extension of heat treatment also results in enzyme inactivation.

Considering the above combined effects of particle size and cooking time on the quality of *Yaabande*, it appears interesting, for improvement of the quality of end product, to integrate, in the traditional processing practice, additional operations of milling and sieving to prepare fine particle size flour. In addition, on cooking, it is preferable to distribute baking tins in monolayer in the cooking pot, in order to allow equal cooking time for all samples. 10 minutes of cooking appears sufficient.

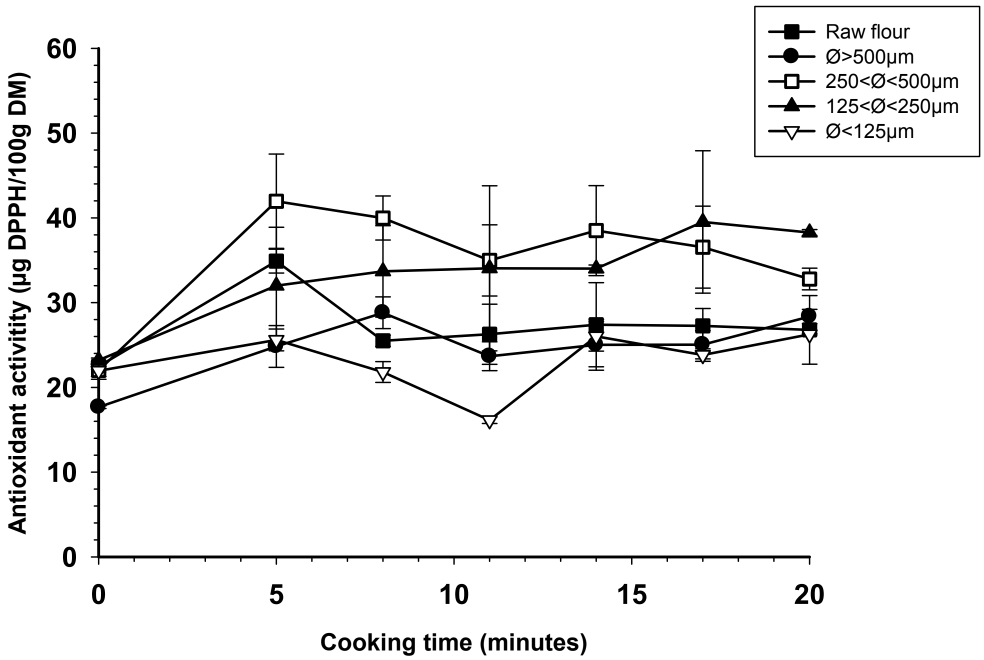

Fig. 8. Combined effect of particle size and cooking time on antioxidant activity of *Yaabande*

4. CONCLUSION

The survey of *Jaabi* production, processing and quality in the savannah region of Cameroon has risen up some critical aspects to target for market spinoff of the product. The analytical results, relating processing practices and product quality, show that the evaluation of processing factors influencing the quality of product is imperative in optimizing the traditional technological conditions of processing. Hence, flour particle size distribution and cooking time are among the main factors affecting the texture and the biological activity of *Yaabande* cake. The antioxidant activity is not significantly affected by cooking time, while the cake is more firm when processed with *Jaabi* flour of very fine particle size (Ø<125µm). Moreover, the traditional process optimisation implies the necessity to address innovation question concerning hardness of pounding operations for flour production. In fine, in order to validate the optimised processing conditions, it appears imperative to assess the acceptability of the product by consumer, as far as particle size of flour and cooking time are concerned.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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