Journal of Food Technology 4 (4): 268-274, 2006

The Influence of Softening Time on Some Textural Characteristics of *Canarium schweinfurthii* Engl. Fruit Pulp at 45°C

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Abstract: The variation of some physical properties of the pulp of *Canarium schweinfurthii* Engl. fruits harvested from Bangangte-Cameroon undergoing treatment at 45°C by wet and dry methods were studied, in order to define optimal softening conditions. Softening by the dry method was done by putting the fruits directly in an oven, whereas the wet process consisted of using water, at 45°C for 0 to 70 min. The variations in mass during softening were evaluated and textural properties of the pulp, was carried out by double compression of the pulp. A gain and a loss of mass were observed during wet and dry softening respectively. It appears that, no matter the method, softening of *Canarium schweinfurthii* Engl. fruits results in a decrease in hardness, springiness, cohesiveness, gumminess and chewiness of the pulp. There is a significant correlation between the textural properties during softening ($r = 0.99$, $p<0.05$). Variations in mass observed are also correlated to the variations in textural properties of the pulp. $r = -0.95$ ($p<0.05$) for the wet method and $r = 0.96$ ($p<0.05$) for the dry method.

Key words: Cameroon, *Canarium schweinfurthii* engl., softening, pulp, physical properties, textural properties

INTRODUCTION

Canarium schweinfurthii Engl. also called aiele is an oleagineous fruit from the Burseracees family heavily present in sub-saharian Africa[1-3]. It produces ellipsoidal fruits similar to European olives which are exclusively consumed soft as snack. These fruits only soften at a well determined set of time and temperature, otherwise they get harden. Aiele fruits, which are highly commercialized in the regional market unfortunately suffer from heavy losses after harvest (≈50% of yearly production). Studies on how to better preserve and soften *Canarium schweinfurthii* Engl. fruits have been conducted[4,5]. Two methods emerged: a wet process (in a bath) and a dry process (in a dryer). For Cameroon fruits, softening is done at 45±4°C for 40 min and 50 to 60 min respectively for wet and dry process[4,5].

Although Tchiegang *et al.*[4,5] defined wet and dry softening conditions for *Canarium schweinfurthii* Engl. fruits, they lack scientific credits able to help establish a metric system for quantifying softening. So far, no study has been done on the physical phenomenon occurring during the softening of canarium fruits. The double compression technic tracking changes in mass, hardness, springiness, cohesiveness, gumminess and chewiness of the pulp fruits as a function of treatment time at 45°C by wet or dry process, may help shed some lights.

MATERIALS AND METHODS

Biological material: The biological material is constituted by the *Canarium schweinfurthii* Engl. fruits from the same tree in Bangangte-west Cameroon. This locality benefits from an equatorial climate as it is located

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at 1600 m altitude between 5°9'N latitude and 10°32'E longitude. The fruits were cooled for 30 h during their transport (by road then air) from the place of harvest to the lab at Ecole Nationale Superieure des Sciences Agro-Alimentaires (ENSAIA) in Nancy-France. They were sorted, thoroughly washed in city water, rinsed in distilled water and then calibrated. Calibration was done according to that of olives set in Codex stand 66[6]. After calibration, fruits of type 2 or big fruits (about 111 to 123 per kg) each weighing about 8.56±0.22 g, with a length of 1.85±0.09 cm, diameter of 0.53±0.04 cm and pulp thickness of 0.31±0.02 cm representing some 94% of the harvest were retained for the study.

Softening: Softening of the fruits was done by the wet process in distilled water[4] and by the dry process at 45°C in a vented Amilabo WTC Binder oven (Germany). Preliminary studies conducted at temperatures from 35 to 65°C indicated 45°C as optimal softening temperature.

Wet method: Softening of the fruits by the wet method in distilled water at 45°C was carried out for 0, 10, 20, 30, 40, 50, 60 and 70 min, respectively as prescribed by Tchiegang *et al.*[4]. 1 Kg batches of *Canarium schweinfurthii* fruits were introduced in 2 L of distilled water at 45°C and the changes in temperature were monitored using a thermometer. Treatment time starts when the water temperature climbs back to 45°C. Three trials were conducted per length of study.

Dry method: Softening of fruits by the dry process was done in an Amilabo WTC Binder oven (Germany) at 45°C with different batches of fruits for the different lengths of study (0 to 70 min). For every temperature/time couple and as in the case of wet softening, a 1 kg batches of fruits is loaded onto the 3rd shelf-about 60 cm wide and a height of 45 cm. Changes in temperature are monitored using a thermocouple embedded in the oven. Treatment time starts when the water temperature climbs back to 45°C. The study is conducted one batch at a time and the next batch is inserted once the temperature has resettled back to 45°C. Three trials were conducted per length of study.

After each length time of treatment by wet or dry method, changes in mass were tracked by way of a precision scale (Sartorious with precision of 0.001) and the state of softening is quantified physically by double compression using the universal instrument LLYOD LRX (Germany).

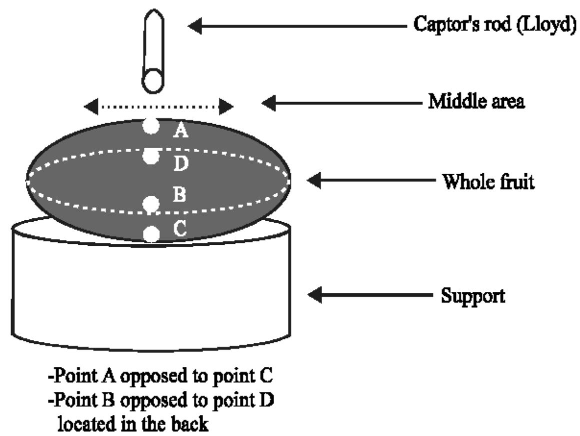

Fig. 1: Location of the sites for double compression on the canarium fruit

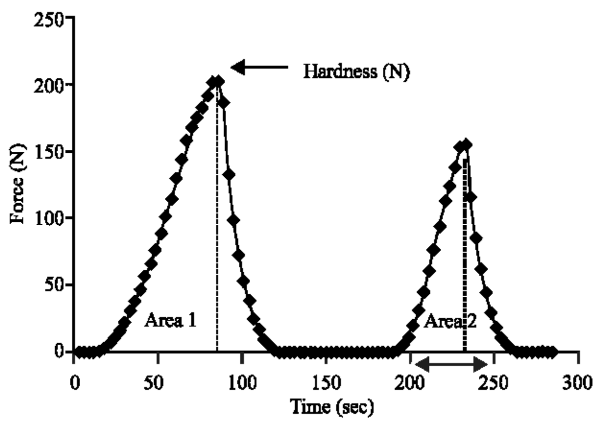

Fig. 2: Instrumental curve of the raw pulp of canarium fruit when doubly compressed down to 80% of its thickness

Evaluation of physical properties

Variations of mass: Variations of the mass of the fruits during softening at 45°C is defined as the ratio (mass of raw fruits-mass of softened fruits)* 100/mass of raw fruits.

Change in textural properties by double compression: Change in textural properties of the pulp of *Canarium schweinfurthii* fruits during treatment by wet or dry softening was done by double compression using the universal instrument LLYOD LRX and the Nexygen software. This software provides a workable data bank and graph from the double compression.

Double compression test: The principle consists of determining the force of the captor necessary to generate a deformation of the pulp down to 80% of its initial thickness (0.31±0.02 cm). Practically, each fruit is submitted to 2 deformations of 2.5 mm at a speed of 2 mm/min by way of a captor with a cylindrical rod of 10 mm diameter and 78.54 mm^2 of area. The captor has a maximum impact force of 500 N with a pre-charge of 0.5 N. The pre-charge here defined as the minimal force it takes to create a contact between the captor's rod and the surface of the fruit indicating the beginning of the experiment. A deformation down to 80% of the thickness of the fruit is highly visible[7,8] and can be defined as 2.5 mm as a reference to the work done on fruits and vegetables. The remaining 20% of the thickness of the pulp is allowed to minimize the resistance from the nucleus. The double compression test was done at 21±1.41°C with a fruit relative humidity of 75.5±0.5%. Figure 1 shows the points of compression on the pulp of fruit. The area of compression on each fruits is preferably around the median and is often divided into 4 equidistant points A, B, C and D. Let's assume two support contact points from the base C and D and two captor's rod contact points A and B. During compression, if point A is in contact with the rod of the captor, point C would be in contact with the support likewise for B and D. Compression from the rod stops at a point once its support has been contacted. 30 fruits were studied per trial during wet or dry softening at 45°C.

Calculations of textural parameters: Hardness, springiness, cohesiveness, gumminess and chewiness were calculated by using the models from: Szczesniak[9], Bourne[10], Sherman[11], Prentice[12] and Ratnakaye *et al.*[7]. Figure 2 indicates the instrumental profile for the raw pulp after double compression. Hardness in Newton (N) is the maximum force yielded after the first deformation or bite. Cohesiveness is the ratio between surface area 2 from the second deformation and surface area 1 from the first deformation. Springiness in millimeter (mm) represents the distance the deformed material travels as it attempts to regain it original state after the deforming force (applied by the captor's rod) has been removed. The gumminess (N) or consistency is the product hardness times cohesiveness whereas chewiness in mJoule (mJ) is the product of gumminess times springiness.

Statistical analysis: The experiments were performed in triplicates and the means±standard deviation of three values were reported. Statgraphics Plus 3.0. was used to analyze the data.

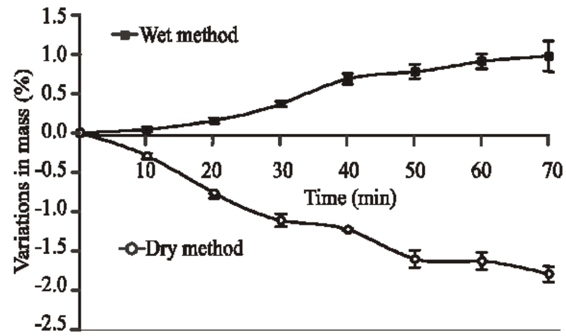

Fig. 3: Variations in mass of pulp as function of time of treatment by wet or dry method at 45°C

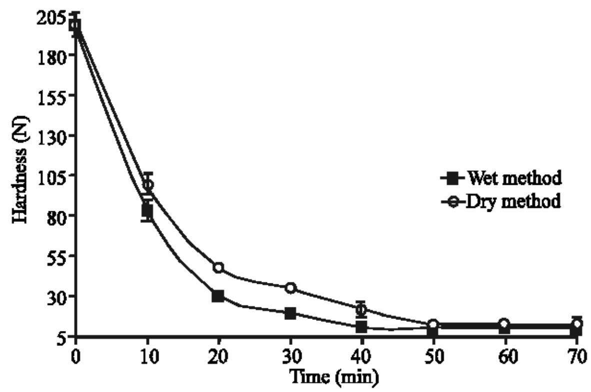

Fig. 4: Hardness of pulp as function of time during treatment by wet or dry method at 45°C

RESULTS AND DISCUSSION

Variations in mass as a function of time of treatment by wet or dry method at 45°C: Figure 3 shows a gain in mass increasing with the time treatment at 45°C and stabilizing after 40 min in the case of wet softening. It also shows a loss in mass increasing with time of treatment and stabilizing between 50 and 70 min in the case of dry softening. The gain in mass resulting from the diffusion of water from the external surface to the interior of the pulp after wet softening is evaluated at 0.97±0.01% whereas the loss in mass observed as water evaporates form both the surface and the pulp when in direct contact with hot aera during dry softening is -1.78±0.09%. These results are in agreement with those found by Tchiegang *et al.*[4] on the *Canarium schweinfurthii* fruits harvested from other regions of Cameroun.

Textural properties as a function of time of treatment by wet or dry method at 45°C: The monitoring of the textural properties of the pulp fruits during wet or dry softening is not only to help explain what happens during

Table 1: Correlation coefficients between the different physical parameters

	Hardness (N)	Springiness (mm)	Cohesivenees	Gumminess (N)	Chewiness (mJ)
Springiness (mm)	0.99* (0.00)				
Cohesiveness	0.99* (0.00)	0.99* (0.00)			
Gumminess (N)	0.99* (0.00)	0.99* (0.00)	0.99* (0.00)		
Chewiness (mJ)	0.99* (0.00)	0.99* (0.00)	0.99* (0.00)	0.99* (0.00)	
Gain in mass (%)	-0.95* (0.00)	-0.96* (0.00)	-0.95* (0.00)	-0.95* (0.00)	-0.95* (0.00)
Loss in mass (%)	0.99* (0.00)	0.96* (0.00)	0.95* (0.00)	0.96* (0.00)	0.96* (0.00)

* = Significant to a degree of probability $p \leq 0.05$ Numbers in brackets represent different probabily thresholds

softening but also to establish a correlation between the changes in mass to those in textural properties.

Hardness: Hardness is the force necessary to generate a deformation after the first bite[13]. In our study it is the maximal force it takes the captor to create a deformation of 2.5 mm from the first bite. Figure 4 shows the same trend in hardness for both modes of treatment at 45°C. Hardness decreases noticeably during the first 40 min of treatment and stabilizes between 40 and 70 min in the study of wet softening and between 50 to 70 min for dry softening. Numbers show 10.78±1.34 and 22.69±3.03 N after 40 min. for wet and dry treatments respectively. However to a threshold of 5%, no difference is seen between wet (10.78±1.34 N) and dry (12.59±1.68 N) methods after 50 min of treatment. There is a significant and negative correlation between the hardness and the gain in mass of the pulp in the study of wet softening at 45°C ($r = -0.95$, $p<0.05$) Table 1 . The harder the fruit the lesser the water migration from the external surface to the interior of the pulp therefore, water migration is responsible for weakening the walls of the pulp and thus its firmness. On the other hand, there is a significant and positive correlation between the hardness and the loss in mass of the pulp in the case of wet softening at 45°C ($r = 0.99$, $p<0.05$) Table 1. In this study the weakness of the walls of the pulp is related to the loss in water resulting in the loss in mass of the fruit. The weakening of the walls of the pulp observed during wet and dry softening is also thought to be caused by the enzymatic activities triggered by treatment at 45°C[14-16].

Springiness: Springiness is the amount of reversible deformation a product can take[13]. It represents the distance the deformed material travels as it attempts to regain it original state after the defor ming force (applied by the captor's rod) has been removed. Figure 5 indicates a decrease in springiness of the pulp with time of treatment and stability between 40 and 50 min for both wet and dry methods. When treated at 45°C for 70 min springiness varies from 1.48±0.14 mm for untreated pulp

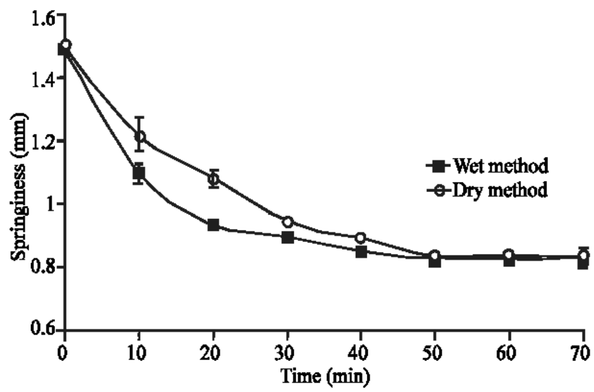

Fig. 5: Springiness of pulp as function of time of treatment by wet or dry method at 45°C

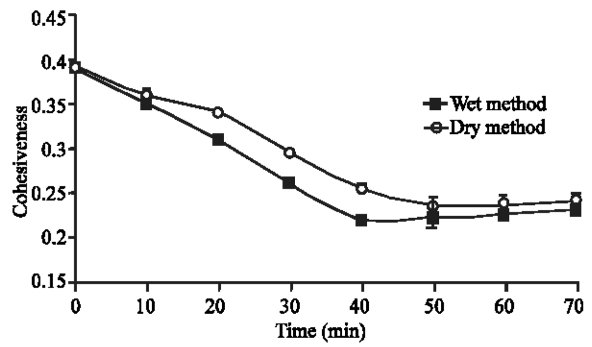

Fig. 6: Cohesiveness of pulp as a function of treatment time by the wet or dry methods at 45°C

down to 0.87±0.06 and 0.87±0.02 mm for wet and dry methods respectively. To a 5% threshold, there is no difference in springiness at 45°C between wet treatment of pulp for 40 min and dry treatment of pulp for 50 min. Table 1 indicates a significantly positive correlation ($r = 0.99$, $p<0.05$) between hardness and springiness of the pulp during treatements of 45°C. The softer the pulp, the lower its capacity to regain its initial state after it's been struck by a deforming force also regarded as weak springiness[9,10]. There is a significant and negative correlation between the springiness and the gain in mass of the fruits ($r = -0.96$, $p<0.05$) in the case of wet treatment versus a significant and positive correlation (r = 0.96, p<0.05) for dry process at 45°C. These results suggest that water migration from outside (wet process) or from inside (dry process) the pulp influences reversibility (springiness) of the pulp. Therefore the transfer of matter (water diffusion) at 45°C contributes to the weakening of the walls of the pulp which in turn loses its reversibility (springiness). The weakening of the walls of the pulp observed during wet and dry softening is also thought to be cause by the enzymatic activities triggered by treatment at 45°C[14-16].

Cohesiveness: Cohesiveness is the amount of deformation (reversible or not) a product can take without rupture[13]. It's the force that binds all the molecules in the product. In our study it is the ratio between surface area 2 from the second deformation and surface area 1 from the first deformation. Figure 6 shows a cohesiveness of the pulp of fruit decreasing over time in both wet and dry treatments at 45°C. This cohesiveness varies from 0.39±0.002 for the untreated fruit down to 0.22±0.002 and 0.23±0.001 when treated at 45°C for 70 min, respectively during the wet and dry processes. As in the study of springiness, to a 5% threshold, there is no difference in springiness of pulp at 45°C between wet treatment for 40 min and dry treatment for 50 min. The decrease in cohesiveness may be explained by the disorganization occurring within the walls of the pulp[17]. The disorganization of the cell walls serving as bond and insuring the integrity of the vegetable[18], also translates into a decrease in hardness and springiness. There is a significant and positive correlation (r = 0.99, p<0.05) between cohesiveness, hardness and springiness of the pulp during softening by wet or dry method Table 1 . To a 5% threshold, there is a significant and negative (r = -0.95, p<0.05) correlation for wet process or one significant and positive (r = 0.95, p<0.05) for dry process, between the cohesiveness and the gain in mass of the fruit Table 1. These results indicate that the transfer of matter (water diffusion) at 45°C by wet or dry method contributes to the reduction in cohesiveness between the cells and thus the softening of *Canarium schweinfurthii* fruits.

Gumminess: Gumminess expresses the consistency of a semi-solid product[11,12]. Figure 7 indicates that gumminess of the pulp decreases in time and stabilizes after 40-50 min in both wet and dry treatments. As in the case of hardness, springiness and cohesiveness, there is no significant difference to a threshold of 5% between the ,

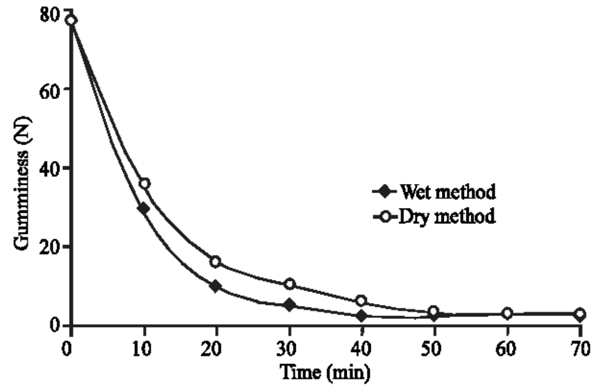

Fig. 7: Guminness of pulp as function of time of treatment by wet or dry method at 45°C

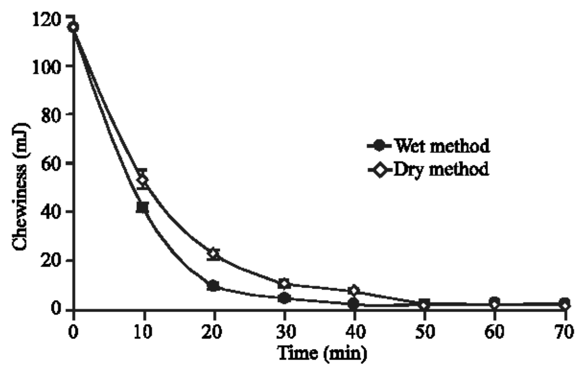

Fig. 8: Chewiness of pulp as function of time of treatment by wet or dry method at 45°C

gumminess of the fruits treated for 40, 50, 60, or 70 min for wet process and those treated for 50, 60, or 70 min for dry process at 45°C. Gumminess are 2.37±0.35 N after 40 min and 2.95±0.64 N after 50 for wet and dry processes respectively. The change in gumminess comparable to that in hardness, springiness and cohesiveness, is a result of its formulation. According to Szczesniack[9] and Bourne[10], gumminess is the product of hardness and cohesiveness. Given that hardness and cohesiveness of the pulp of *Canarium schweinfurthii* fruits decrease during treatment at 45°C in both wet and dry processes their product explains the behavior in gumminess. To a threshold of 5%, there are significantly positive and perfect correlations Table 1 between hardness, springiness, cohesiveness and gumminess during treatment at 45°C (r = 0.99, p<0.05). There is a significant and heavily negative (r = -0.95, p<0.05) correlation for wet process or one significant and heavily positive (r = 0.96, p<0.05) for dry process, between gumminess and the gain in mass of the fruit. These results indicate that the transfer of matter (water diffusion) at 45°C by wet or dry method contributes to the reduction of the consistency of the pulp of the *Canarium schweinfurthii* fruits during softening by the wet or dry processes at 45°C.

Chewiness: Chewiness of the pulp decreases with time of treatment at 45°C and stabilizes after 40 and 50 min for both wet and dry methods, respectively Fig. 8. To a threshold of 5%, there is no difference between wet treatment for 40 min (2.12±0.21 mJ) and dry treatment for 50 min (2.46±0.24 mJ). Changes in Chewiness similar to that of hardness, springiness, cohesiveness and gumminess can be explained by its formula. According to Szczezsniak[9], Bourne[10], Sherman[11], Prentice[12] and Ratnakaye *et al.*[7], chewiness is the product of gumminess and springiness. Given that gumminess and springiness decrease with time, chewiness is expected to behave likewise. The correlation observed between chewiness and the change is mass of the fruits by wet and dry process are similar to that with gumminess ($r = -0.95$ (wet process); $r = 0.96$ (dry process)). These results suggest that, from a physical point of view, a gain (wet process) or a loss (dry process) in mass contributes to the weakening of the walls of the pulp of the *Canarium schweinfurthii* fruits thus making it easy to digest (chewiness).

CONCLUSION

From the two methods of treatment of *Canarium schweinfurthii* fruits at 45°C, it appears on a physical aspect that softening is a result of a decrease in hardness, springiness, cohesiveness, gumminess and chewiness of the pulp. There is a significantly positive correlation between the changes in textural properties ($r = 0.99$, $p<0.05$). Physical changes (gain or loss in mass) are also correlated to changes in texture.

ACKNOWLEDGMENT

The authors thank AIRE-*développement* (Agence Internationale pour la Recherche à l'Etranger) Paris-France, AUF (Agence Universitaire de la Francophonie) Paris-France and IFS (International Fondation for Science) Stockholm-Sweden for their financial and logistical support.

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