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Pasteurization of a pulpy and fibrous nectar: The case of baobab (*Adansonia digitata* L.)

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Abstract

Baobab fruit nectar is a good source of energy in the form of carbohydrates, vitamin C, dietary fiber and essential minerals. However, its shelf life remains limited due to the lack of suitable heat treatment. The pasteurization optimization tests consisted of proposing an ideal scale for optimal preservation of the nectar. Thus, the minimum pasteurizing value of 30 minutes allowing the elimination of pathogenic and spoilage flora, resulted in the optimized scale of 70 °C for 25 minutes. The latter, coupled with a conservation at 4 °C, ensures excellent preservation of the organoleptic qualities of color and nutritional vitamin C for 40 days.

Keywords: Nectar; Pasteurization; Stability; *Adansonia digitata* L

1. Introduction

The african baobab (*Adansonia digitata* L.) is an emblematic tree of the African savannah [1] wich can reach more than 1000 years [2] and attempt 35m in height [3]. The different parts (leaves, bark, roots, seeds, fruit pulp, flower) are widely used as food or traditional medicine [2,3]. The fruit is the most exploited and used part of the baobab [2,4,5]. Currently, the consumption of baobab fruits tends to spread in many areas of the globe. This craze is explained by its richness in vitamin C (200-500 mg/100 g) [3], essential minerals (calcium : 250-655 mg/100g, phosphorus : 96-210 mg/100g, iron : 1,4-7,6 mg/100g), total polyphenols (63.56 ± 0.79 mg/g EAG) [2,5], dietary fiber (1,1–43 g/100g) [3,6]. Despite its interesting nutritional characteristics, its economic contribution and its strong technological potential, the baobab fruit remains essentially exploited in an artisanal way through small businesses and processing units in the form of nectars.

The fruit's richness in soluble and insoluble fiber and dry matter makes its nectar very pulpy. Thus, the texture of the nectar does not lend itself to sterilization and does not lend itself well to conventional pasteurization scales used for juice at 80 ± 2 °C and held at different treatment times (1, 2.5, 5, 10, and 15 min) [7–9] and certain nectars (73-90 °C for 10-15 min) [4,5,10] This explains why in practice, the pasteurization scales applied to baobab nectar are poorly adapted, thus limiting their shelf life on local, regional and international markets [5]. In this context, optimizing pasteurization would make it possible to guarantee microbiological, nutritional and organoleptic stability of baobab fruit's nectar.

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2. Material and methods

2.1. Nectar production

The nectars were prepared from baobab fruits harvested in the Kaolack area (Senegal). Starting from a 1/6 ratio (fruit/water), the whole seeds were kneaded with water to extract the pulp. The final nectar is obtained by adding sugar (Figure 1).

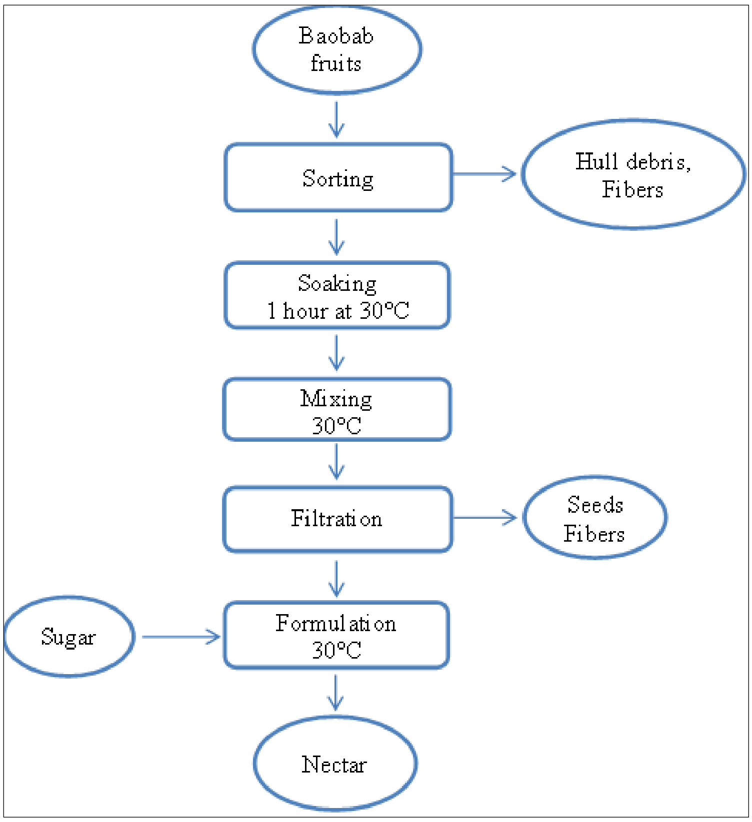

Figure 1 The production diagram of Baobab fruit nectar

2.2. Physicochemical and biochemical analyses

pH, titratable acidity, soluble solids content, reducing and total sugars were analyzed on baobab fruit nectars according to standard AFNOR methods [11]. Vitamin C is measured by volumetric titration with 2,6-dichlorophenol-indophenol (DCPIP). Ascorbic acid being a reducing compound, it is neutralized by means of an oxidant, DCPIP which also serves as a colored indicator [12].

2.3. Microbiological analyses

Microbiological analyses made it possible to evaluate the effectiveness of the pasteurization scales applied. The standards and culture media used are presented in table 1 according to French standards [13].

Table 1 Standards and culture media used for microbiological analyzes

Germs	References	Culture media	Temperature and incubation time
Total flora	NF EN ISO 4833	Plate Count Agar)	30 °C / 24 h
Lactic acid bacteria	NF V 04-503	Man, Rogosa, Sharpe	30 °C/72 h
Yeats and Molds	NF EN ISO 7954	Sabouraud with chloramphenicol	30 °C/72 h

2.4. Optimization of nectar pasteurization

The pasteurization optimization tests consisted in determining the minimum pasteurization value allowing to obtain the microbiological and nutritional stability of baobab fruit nectar. The pasteurization value corresponds to the duration of a treatment leading to the same reduction in the number of microorganisms carried out at the reference temperature. In the case of baobab fruit nectars, pasteurization is carried out at a constant temperature of 70°C with variable stages: 30, 85, 140, 195 and 250 minutes. The minimum pasteurization value allows to calculate the corresponding stage duration at pasteurization temperatures of 70, 75, 80, 85 and 90 °C using the formula (1).

$$t_\theta = VP_{\theta ref} \times 10^{\frac{\theta_{ref}-\theta}{z}} \quad \dots\dots\dots\dots.. \ (1)$$

t_θ : duration of treatment (minutes)
$VP_{\theta ref}$: pasteurizing value at reference temperature (minutes)
z : temperature difference likely to divide the decimal reduction time by 10.

2.5. Data analyses

Data analyses consisted of variance analysis at the 5% threshold and principal component analysis using Statistica 7.1 software.

3. Results and discussion

3.1. Determination of the minimum pasteurizing value

The efficiency of pasteurization is assessed by the applied pasteurization values (Table 2). The pasteurization values calculated using equation (1) take into account the temperature rise (11-18 min) and cooling (14-32 min) times.

Table 2 Pasteurizing values of the different scales applied to baobab fruit nectar

	Pasteurization scale (°C/min)	**Pasteurizing value (min)**
Essay 1	70/30	36
Essay 2	70/85	91
Essay 3	70/140	146
Essay 4	70/195	202
Essay 5	70/250	257

The pasteurizing values tested ensure a total absence of germs at 70 °C (Table 3). Other studies have resulted in the same microbiological reduction for temperatures from 70 °C to 95 °C, after 10 min of treatment [14]. Also, the high acidity of the nectar of the baobab fruit [3,5] like that of orange [15], strongly limits yeasts, molds and lactic acid bacteria [16,17]. Nutritional criteria are then decisive in choosing the best pasteurization conditions.

Table 3 Microbiological evaluation in CFU/ml according to pasteurizing values

	Pasteurizing value (min)					
Microorganisms	**Unpasteurized**	**Essay 1**	**Essay 2**	**Essay 3**	**Essay 4**	**Essay 5**
Total flora	$1.5.10^3$	0	0	0	0	0
Lactic acid bacteria	625	0	0	0	0	0
Yeasts and molds	1.10^3	0	0	0	0	0

The biochemical characteristics of nectars before and after pasteurization reveal a reduction in vitamin C and sugar contents (Table 4). Vitamin C losses vary from 35.60 to 57.69% depending on the pasteurization values applied (Figure 2). The degradation of vitamin C or ascorbic acid occurs aerobically and then anaerobically leading to the formation of brown pigments in the form of reductones. Furthermore, the reduction in sugar concentration (13.20 g/100 ml; 12.93; 12.82; 13.36; 13.93) and the increase in the browning index (36.59; 39.38; 39.38; 40.18; 42.65) respectively at the pasteurizing values, are correlated with the Maillard reactions [18–20]. However, pasteurization had no significant effects on pH, soluble solids and titratable acidity values. The 30-minute pasteurization value is subsequently used for the search for the best pasteurization scale.

Table 4 Physicochemical characteristics of nectars according to pasteurizing values

	Pasteurizing value (min)					
	Unpasteurized	**Essay 1**	**Essay 2**	**Essay 3**	**Essay 4**	**Essay 5**
pH	3.41 ± 0.01^{a}	3.38 ± 0.01^{a}	3.38 ± 0.02^{a}	3.37 ± 0.03^{a}	3.34 ± 0.06^{a}	3.38 ± 0.01^{a}
Titratable acidity (mEq/100ml)	5.14 ± 0.04^{a}	5.09 ± 0.07^{a}	5.16 ± 0.07^{a}	5.14 ± 0.08^{a}	5.12 ± 0.01^{a}	5.17 ± 0.01^{a}
Soluble dry matter (g/100ml)	14.00 ± 0.01^{a}	14.00 ± 0.01^{a}	14.00 ± 0.01^{a}	14.00 ± 0.01^{a}	14.13 ± 0.09^{b}	14.13 ± 0.09^{b}
Sugars (g/100ml)	12.39 ± 0.12^{a}	13.20 ± 0.08^{b}	12.93 ± 0.05^{c}	12.82 ± 0.05^{d}	13.36 ± 0.12^{e}	13.93 ± 0.05^{f}
Vitamin C (mg/100ml)	6.90 ± 0.08^{a}	4.50 ± 0.05^{b}	4.00 ± 0.08^{c}	3.20 ± 0.05$^{d.e}$	3.50 ± 0.05$^{c.d}$	2.90 ± 0.05^{e}
Browning index	30.96 ± 0.01^{a}	36.59 ± 0.01^{b}	39.38 ± 0.01^{c}	39.38 ± 0.01$^{c.d}$	40.18 ± 0.01$^{c.d}$	42.65 ± 0.01^{d}

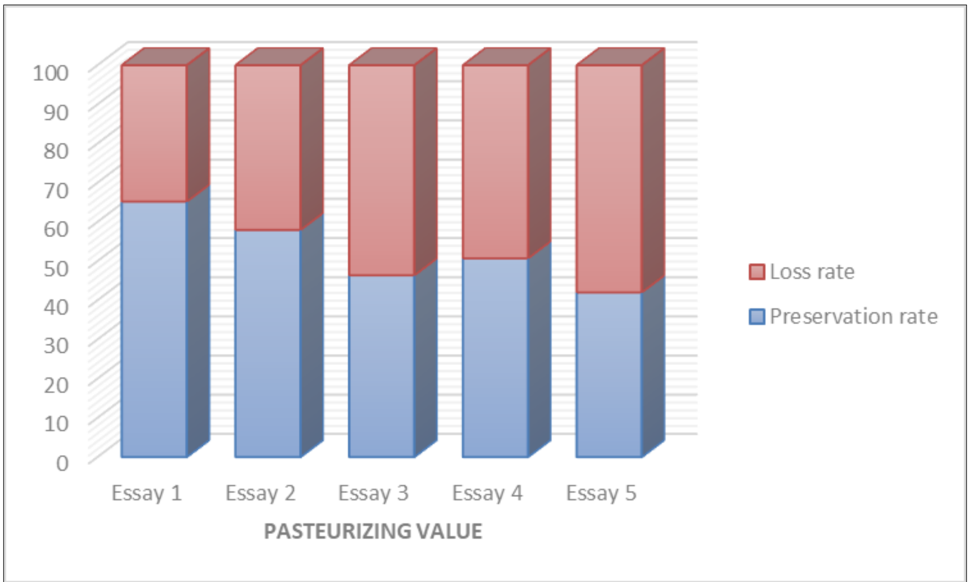

Figure 2 Influence of pasteurization value on vitamin C

3.2. Determination of the pasteurization scale

Pasteurization tests were carried out on five scales (70 °C/25 min, 75 °C/3 min, 80 °C/1 min, 85 °C/1 min and 90 °C/1 min) calculated from the minimum pasteurization value of 30 minutes. The physicochemical characteristics of the treated nectars are statistically similar (Table 5). However, the factorial plan of the principal component analysis shows a positive correlation between the vitamin content and the scale of 70°C/25 min (Figure 3). Also, storage at 4 and 45°C for 10 days reveals significant losses of vitamin C proportional to the pasteurization temperature (Table 6). The work of Gomez has proven that the duration of the vitamin C degradation reaction is reduced at high temperature: 267 min at 70 °C; 183 min at 80 °C; 150 min at 85 °C and 125 min at 90 °C [21]. Other research has supported the catalytic effects of dissolved oxygen in vitamin extracts [22,23]. In baobab fruit nectars, treatments at 80 and 90 °C led to much greater losses of vitamin C. Indeed, the levels measured on pasteurized nectars were 50 to 60% lower than those measured on the initial nectar (Figure 4). The nutritional quality of the drink was therefore significantly degraded in terms of vitamin content [5].

Table 5 Physicochemical characteristics of pasteurized nectars

	Unpasteurized	**70 °C/25 min**	**75 °C/3 min**	**80 °C/1 min**	**85 °C/1 min**	**90 °C/1 min**
pH	3.41 ± 0.01	3.38 ± 0.01[a]	3.38 ± 0.02[a]	3.37 ± 0.03[a]	3.34 ± 0.06[a]	3.38 ± 0.01[a]
Titratable acidity (mEq/100ml)	5.14 ± 0.04	5.09 ± 0.07[a]	5.16 ± 0.07[a]	5.14 ± 0.08[a]	5.12 ± 0.01[a]	5.17 ± 0.01[a]
Soluble dry matter (g/100ml)	14.00 ± 0.01[a]	14.00 ± 0.01[a]	14.00 ± 0.01[a]	14.00 ± 0.01[a]	14.13 ± 0.09[b]	14.13 ± 0.09[b]
Sugars (g/100ml)	12.39 ± 0.12[a]	13.20 ± 0.08[b]	12.93 ± 0.05[c]	12.82 ± 0.05[d]	13.36 ± 0.12[e]	13.93 ± 0.05[f]
Vitamin C (mg/100ml)	6.90 ± 0.08[a]	4.50 ± 0.05[b]	4.00 ± 0.08[c]	3.20 ± 0.05[d.e]	3.50 ± 0.05[c.d]	2.90 ± 0.05[e]
Browning index	30.96 ± 0.01[a]	36.59 ± 0.01[b]	39.38 ± 0.01[c]	39.38 ± 0.01[c.d]	40.18 ± 0.01[c.d]	42.65 ± 0.01[d]

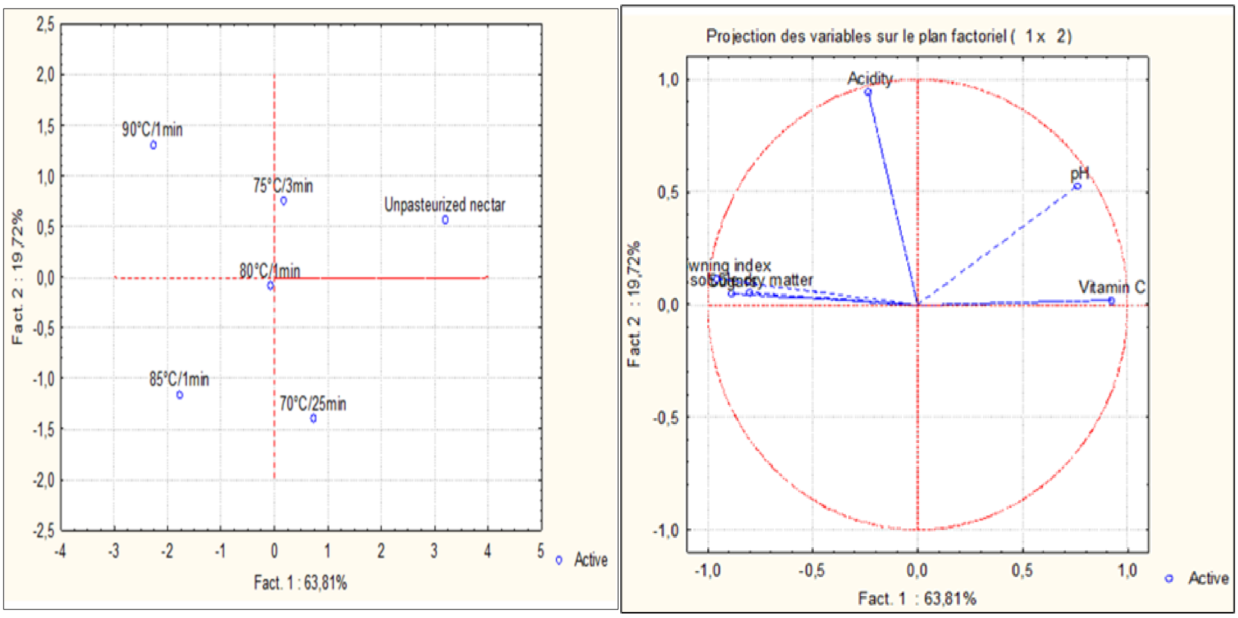

Figure 3 Factorial plan of pasteurization scales

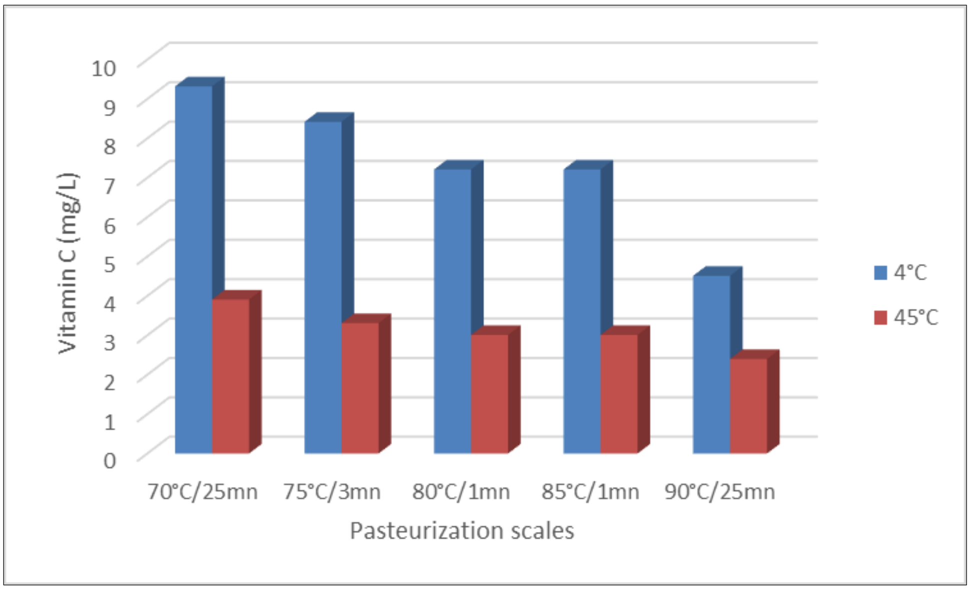

Figure 4 Vitamin C contents of nectar after 10 days of storage at 4 and 45 °C

The pasteurization scales established in the literature on baobab fruit nectars are effective from a microbiological point of view [4,14]. Furthermore, pasteurization at 80 °C/10 min induces significant degradation of polyphenols [24]. In the case of 90 °C/10 min the losses are 66% in vitamin C coupled with a significant alteration of the color parameters [4]. In this sense, the scale of 70 °C/25 min which emerges from this study remains relevant both in terms of microbiological quality and preservation of nutrients of interest (preservation of 40% of vitamin C after 40 days of storage at 4 °C).

4. Conclusion

The optimization tests of the pasteurization of the nectar of the baobab fruit resulted in an optimal scale of 70 °C for 25 minutes. The latter, coupled with a conservation at 4 °C, made it possible to maintain the stability of the nectar for 40 days with a good preservation of the microbiological, nutritional and organoleptic qualities.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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