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Original Research Article

Optimization of process conditions for jam production from plantain-like hybrid (*CARBAP K74*) grown in two agro- ecological zones of Cameroon

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This study was undertaken in order to optimize the conditions for the manufacturing of jams from *CARBAP K74* pulps grown in 2 localities of Cameroon (Njombe and Bansoa respectively situated at 80m and 1350m above sea level). This plantain-like hybrid was chosen because of its agronomic and postharvest performances as well as its BSV-free viral state. The central composite was used to investigate the effect of different variables like pulp quantity, sugar quantity and cooking time that may have an impact on jam quality. Optima conditions were determined for each response (total titratable acidity and pH) and optima formulations were selected for sensory evaluation using the 9-point hedonic scale. The shelf-life was evaluated through microbiological and physico-chemical analyzes over 21 days at 4°C and 25°C. Optimization results showed that, total titratable acidity was influenced by the quantities of pulp and sugar as well as cooking time. However, the pH was only influenced by pulp quantity. The factor levels for the formulation that maximized the total titratable acidity and pH coded as jams made of Bansoa pulps and as jams made of Njombe pulps were determined. The sensory evaluation results showed that jams made with Bansoa pulps exhibited highest overall acceptability, thus indicating that the location (high altitude) influenced positively the sensorial quality of the jams. Jam samples remain good for consumption during 21 days of storage at 4°C. This study clearly indicated that banana and plantain pulps in general, as well as plantain like hybrid pulps (*CARBAP K74)* in particular, are suitable for jam formulations.

Key words: Jam, optimization, sensory-analysis, shelf-life, *CARBAP K74-cultivar*

INTRODUCTION

Nowadays, most of the available banana and plantain species are derived from the *Musa acuminata* (Genome A) and the *Musa balbisiana* (Genome B) species following many natural or artificial hybridations, of which some of these species display illnesses such as black Sigatoka (IITA, 1992; Swennen, 1990). It is under the framework of developing *Musa* hybrids, partially or totally resistant to pests and diseases, that a plantain like hybrid, namely *CARBAP K74* was created in 2010 by African Research Centre on Bananas and Plantains (CARBAP, 2012). *CARBAP K74* exhibits highly appreciated agronomic and postharvest performances (partial resistance to nematodes and weevils, yield, fruit weight, pulp color, etc.), but presents peculiar properties such as plantain characteristics when it is unripe and when ripe it has the particularity of banana. *CARBAP K74* at the ripe stage, its pulp present two poor characteristics: (1) it doesn't have the same taste as normal plantain or dessert banana, therefore not appreciated by the consumers; and (2) its pulps can't be cooked and consumed as local plantains or other cooking bananas. Therefore, processing the pulps of this hybrid into an aggregate valued-product such as jam becomes an alternative for the use of this fruit at ripen stage, as it would enable the valorisation and help avoid post-harvest losses (Ngoh Newilah et al., 2016).

Jam is a gelatinized product obtained from fresh fruits that are boiled with sugar, with or without added pectin and acid. The final concentration of jams is determined by the current standards. The products presented in containers sealed and stability is ensured by heat treatment (Adriana, 2011). However, the quality of jam is influenced by many factors such as fruit quality, high pectin content, relatively low pH and high total soluble solids (Ahmed, 2007). According to Pereira et al. (2011), pulp to sugar ratio is an important determinant of jam quality since it has a great impact on the titratable acidity and water activity of jam. Also, the interaction time–temperature had significant effects on jam's pH and titratable acidity; meanwhile cooking conditions have an impact on volatiles compounds in jam (Touati et al., 2014; Lesschaeve et al., 1991). Ngoh Newilah et al. (2016) tested the potential uses of *CARBAP K74* fruits and found that unripe ones could be transformed into good quality flours used for bread, donuts and cake manufacturing. Also, their preliminary tests concluded that ripen pulps could be suitable for jam formulation. Based on the above potential uses of *CARBAP K74*, and some studies conducted on jam from banana and other fruits, the variations of the quantities of ingredients influence the quality of jam. Also, cooking time and optimum conditions are required to obtain best quality jam. Therefore, this study aimed to optimize the processing conditions for jam production using *CARBAP K74* pulps, thus leading to the valorisation of this plantain-like hybrid. Specifically, the study intends to analyse the influence of the quantity of pulp and sugar, as well as cooking time on the quality of jam. It also aim at determining the optimum processing conditions and evaluate the acceptability and shelf life of the optima jam formulate.

MATERIALS AND METHODS

Description of the study area

These experiments were realized at the Postharvest Technology Laboratory of the African Research Centre on Bananas and Plantains (CARBAP) situated in Njombé and at the Laboratory of Biochemistry, Medicinal Plants, Foods Sciences and Nutrition (LABPMAN) of the University of Dschang – Cameroon. The experimental plots where the bunches were harvested are located in Bansoa (Penka – Michel Subdivision, Menoua Division, West Region – Cameroon; described as western highlands) and in Njombe (Njombe – Penja Subdivision, Moungo Division, Littoral Region – Cameroon; described as humid forest zone with bimodal rainfall).

Experimental design

Presentation of factors and experimental domain

Response Surface Methodology (RSM) was used in this study to determine the optimum levels of the ingredients for jam. The effect of three Independent variables [pulp quantity (X1), sugar quantity (X2) and cooking time (X3)] on two response variables (total titratable acidity and pH) were evaluated. The central composite design (CCD) 2^3 + star was used. In this type of design, each of the independent variables is taken at two levels meaning that each variable has a low and high numeric value. A coded numeric value of - 1 and +1 is assigned to represent the variable's low and high values. In this case where we had 3 factors, we had two trials for the central points, 8 trials for the factorial design, 2 trails for the first factor at the axial point, 2 trials for the second factor at the axial point, 2 trials for the third factor at the axial point; making a total of 16 trials (Myers, 1999). The use of the CCD helps (a) to study the main effect of parameters, (b) to create models between the variables and (c) to determine the effect of these variables to optimize the levels of ingredients (Sayed et al., 2013). The RSM was employed to optimize the process ingredients like pulp, sugar and cooking time. The range of these three ingredients are given in Table 1. The experimental domains were determined after preliminary test (Table 1) and sixteen formulations were generated (Table 2) using statgraphic 5.0 software, a second order polynomial model including the interaction effects according to Equation 1.

$$(1) Y = I + ax_1 + bx_2 + cx_3 + dx_1^2 + ex_1x_2 + fx_1x_3 + gx_2^2 + hx_2x_3 + ix_3^2 + \varepsilon.$$

where Y is the measured response; I is a constant; a, b and c are linear coefficients; d, g and i are square coefficient; e, f and h are interaction coefficient; x_1, x_2, x_3, x_1^2, x_1x_2, x_1x_3, x_2^2, x_2x_3, x_3^2 are levels of independent variables and ε is the error.

The criterion used to accept the proposed model was given by the high determination coefficient (R^2) value, assumed as a value exceeding 75%, leading to the conclusion that the model explains a high percentage of the total variability (Joglekar and May, 1987). The coefficient estimates significance was analyzed aiming at verifying which factor better contributed to the adjustment of the model considering a 5% level of significance.

Preparation of jam

Fresh bunches of *CARBAP K74* were harvested from experimental plots settled in two contrasted agro-ecological zones, namely Bansoa (at 1350 m above sea level) and Njombe (at 80 m above sea level) respectively in August and September 2014 within the framework of C2D/PAR – PLANTAIN Project. The bunches were transported to the post-harvest laboratory of CARBAP and kept at ambient temperature for ripening until maturation stage 7 (fruit completely yellow with black spots). At this

Table 1. Coded levels and real values of factors

Command variable	Coding levels				
	-α (-1.73)	-1	0	+1	+ α (+1.73)
	Real values				
Quantity of pulp X_1 (g)	164.77	250.00	375.00	500.00	585.22
Quantity of sugar X_2 (g)	140.91	175.00	225.00	275.00	309.09
Cooking times X_3 (mins)	30.90	35.00	41.00	47.00	51.09

Table 2. Experimentation matrix for optimization and non-variable factors

Trial	Experimental matrices			Real values			Non variable factors	
	X_1	X_2	X_3	X_1 (g)	X_2 (g)	X_3 (g)	VW (ml)	VL (ml)
1	0	0	0	375.0	225.0	41.0	375.0	150.0
2	-1	-1	-1	250.0	175.0	35.0	250.0	250.0
3	-1	-1	+1	250.0	175.0	47.0	250.0	250.0
4	+1	-1	-1	500.0	175.0	35.0	500.0	200.0
5	- α	0	0	164.8	225.0	41.0	164.8	65.9
6	0	0	- α	375.0	225.0	30.9	375.0	150.0
7	0	0	+α	375.0	225.0	51.1	375.0	150.0
8	0	+α	0	375.0	309.1	41.0	375.0	150.0
9	+1	-1	+1	500.0	175.0	47.0	500.0	200.0
10	0	0	0	375.0	225.0	41.0	375.0	150.0
11	- 1	+1	+1	250.0	275.0	47.0	250.0	250.0
12	+ α	0	0	585.2	225.0	41.0	585.2	234.1
13	+1	+1	-1	500.0	275.0	35.0	500.0	200.0
14	-1	-1	-1	250.0	275.0	35.0	250.0	250.0
15	0	+α	0	375.0	140.9	41.0	375.0	150.0
16	+1	+1	+1	500.0	275.0	47	500.0	200.0

X_1 = Quantity of pulp, X_2 = Quantity of sugar, X_3 = Cooking times, VW = volume of water, VL = volume of lime.

stage, fruits were washed and peeled. Pulps were sliced into small pieces and ground with different quantities of water as shown in Table 2. These ground pulps were boiled with appropriate quantity of sugar as shown Table 2 and cooked using an electric cooker. When the temperature was around 60°C; different volumes of lime juices was added (Table 2).This mixture was then stirred tilled the gelling of jam was noticed using a spoon taste (Ahmed, 2007). It was then cooled and then packed in bottles (105ml glass jam jar). Pectin was not used during jam production. According to the modified jam production protocol of Fasogbon et al. (2013), the cooking temperature was between 70°C to 102°C.

Determination of pH

5 g of each produced jam samples were diluted with 50ml distilled water to make a 10% solution. The pH was measured using a pH meter (Inolab, pH level 2) which was calibrated at room temperature using buffer solutions at pH 4 and 7 (IAL, 2005).

Determination of the total titratable acidity (TTA)

6g of each formulated jam were sampled and introduced into a 250ml beaker, then 50ml distilled water were added and stirred with an agitator for 2 min until a homogenate solution was obtained. From this solution 10 ml were pipetted and placed in a different beaker onto which 3 drops of phenolphthalein was added. This was then titrated with 0.1 N NaOH solution to an end point of 8.2 and the volume of NaOH solution was recorded. The total titratable acidity was calculated using the formula below and expressed in percentage of malic acid (modified method of the AOAC, 2000).

% acid= (mls NAOH used×0.1N NAOH×milliequivilent factor×100) / (grams of samples) Milliequivalent factor of malic acid is 0.067

Sensory evaluation of optima jams formulation

Our panel constituted of 60 untrained people of both sex, been individuals from the Dschang university campus, personnel of IRAD and CARBAP Njombe. They were asked to give colour, aroma, taste, texture, global acceptability of the jam samples that were coded using a three letter using a 9-point structured hedonic scale (9 = like extremely to 1= dislike extremely).

The sensory tests were carried out at the Postharvest Technology Laboratory of CARBAP. They were done

Table 3. Regression coefficients (RC), *p* values and coefficient of determinations (R^2) for total titratable acidity (TTA) and pH for Njombe and Bansoa jam.

Sources	Bansoa jam				Njombe jam			
	TA		pH		TA		pH	
	RC	P-value	RC	P-value	RC	P-value	RC	P-value
X_1:QP	0.0028	0.0257*	0.000034	0.0434*	0.001	0.041*	-0.0002	0.048*
X_2:QS	0.006	0.0109*	0.0043	0.1437	-0.005	0.0001*	0.0033	0.175
X_3:CT	0.076	0.0441*	0.043	0.5808	-0.017	0.002*	0.0312	0.612
X_1X_1	-0.000005	0.0289	4.12E-7	0.1664	-0.000002	0.002	-8.601E-8	0.774
X_1X_2	0.000005	0.3169	-6.E-7	0.4265	0.000002	0.063	-6.E-7	0.465
X_1X_3	-0.00001	0.7522	0.000012	0.0937	-0.000004	0.653	0.00001	0.119
X_2X_2	-0.00002	0.1323	-0.00001	0.0059	0.000003	0.208	-0.000004	0.037
X_2X_3	-0.00002	0.8250	-0.00002	0.2051	0.00005	0.048*	-0.00002	0.241
X_3X_3	-0.0007	0.3481	-0.0005	0.0037	0.0001	0.414	-0.0004	0.022
Constant	-2.34		2.532		1.185		2.90466	
R^2	76.16 %		88.24 %		96.79 %		82.39%	

* Independent variable that significantly ($p < 0.05$) affect the response

according to the AFNOR XP V 09-500 standards entitled: "General guidelines for the performance of hedonic tests in sensory evaluation laboratories or in controlled conditions involving consumers". The consumer panel consisted of sixty (60) people of different levels of schooling, different occupations, males and females of various age groups. All these people resided in the localities of Njombé - Penja and its surroundings in the Littoral Region as well as in Dschang, a university town closer to Bansoa.

During the tests, consumers were invited to taste each form of jam one after the other after rinsing their mouth each time with water. They then gave their opinions on the colour, taste, texture, aroma and overall appreciation of each product tasted on a 9-point hedonic scale: 9 (I like extremely) to 1 (I do not like) as described by Koko et al. (2012).

Shelf-life of optima jams formulation

The different coded optima formulations were stored at refrigerated (4°C) and ambient temperature (25°C). Physicochemical and microbial analyses were performed every seven days within three weeks. The physicochemical parameters pH and total titratable acidity were evaluated using the above described methods, moisture content and dry matter content were evaluated using the AOAC. (2000) and total soluble solid determined using the modified method of Dadzie and Orchard. (1997). For microbial analysis, yeast and mould were enumerated using the method of Bhavana Soni et al*.* (2013).

Statistical analysis

The above collected descriptive data were analyzed using ANOVA Statgraphic plus 5.0 software and response surface curves were drawn using sigma plot 11.0. Concerning sensory evaluation and shelf-life, mean results analyses were done using R software 3.3.0. Analysis of Variance (ANOVA) to determine the level of significance. Mean separation was carried out by using LSD at 5% level of significance. .

RESULTS AND DISCUSSION

Regression equations and analysis of variance

The Polynomial models for the various responses total titratable acidity (TTA) and pH for both jams obtained from *CARBAP K74* grown in Njombe and Bansoa can be generated from the data from the ANOVA Table 3, as a function of the quantity of pulp (X_1), quantity of sugar (X_2) and cooking time (X_3).

According to the ANOVA results, total titratable acidities (TTAs) of jams from these two zones were influenced significantly by the three studied factors namely quantity of pulp, quantity of sugar and cooking time. The same significant influence of quantity of pulp and sugar was obtained by Pereira et al. (2011) on the effect of different ingredients contents on physical, physicochemical and sensory properties of the creamy banana marmalade cv. ‘nanica’ (*Musa cavendish*). The interaction between the quantity of sugar and the cooking time was significant for jam produced using *CARBAP K74* cultivated in Njombe (Table 3) this proves the impact of agro-ecological conditions on the plantain-like hybrid pulps. The coefficients of determination R^2 were 76.15 % and 96.72 % respectively for jams derived from fruits harvested in Bansoa and Njombe. Because R^2 is higher than 75%, we concluded that the experimental values were equivalent to the predicted theoretical model values (Joglekar and May, 1987).

pH on the other side was in linear terms with the quantity of pulp only as it effects was significant at $p<0.05$ (table 3) similar effect was obtained by Igor et al*.* (2011) when working on the Influence of passion fruit albedo, citric acid,

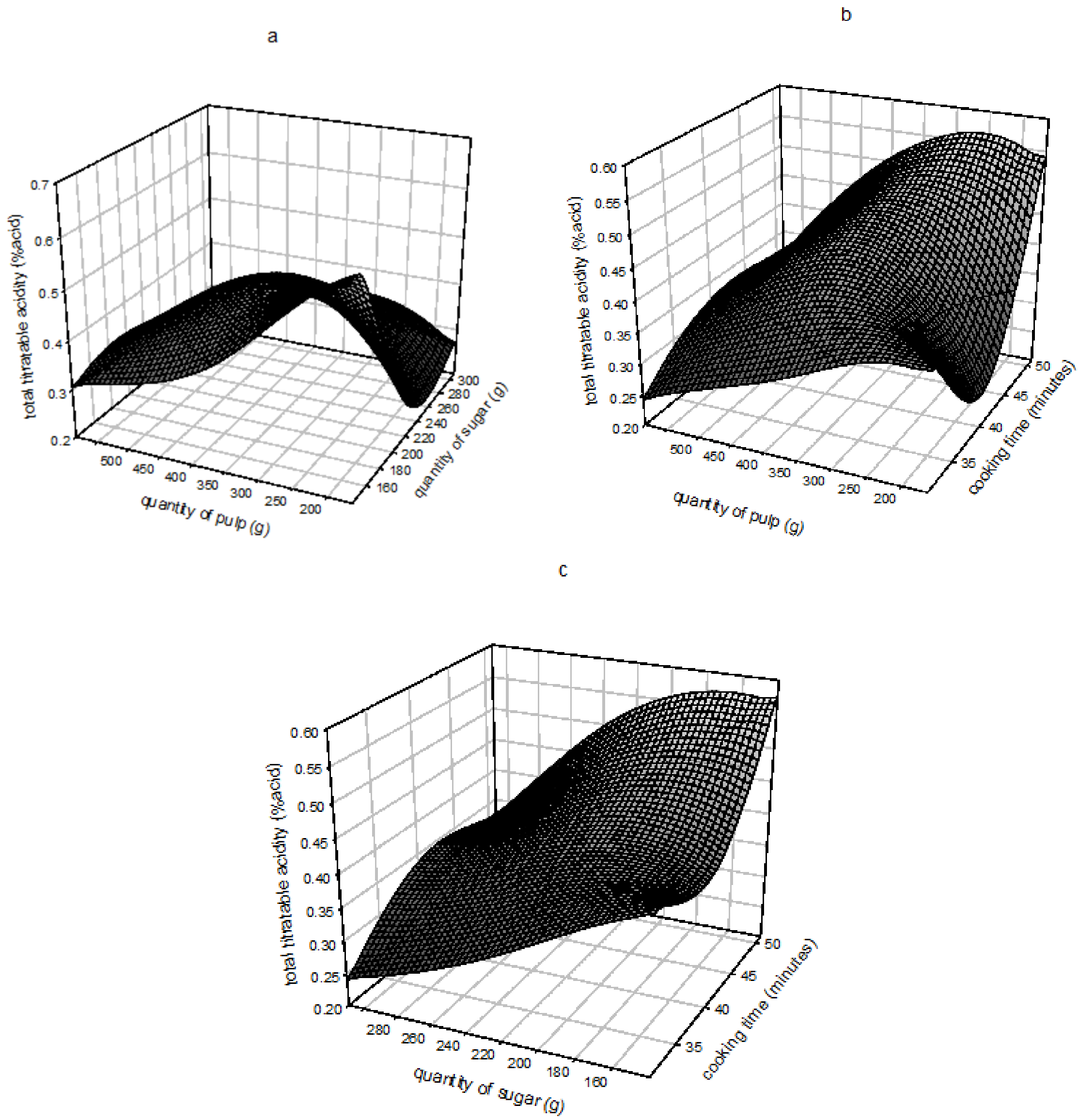

Figure 1: Response surface plots showing the effect of quantity of pulp and quantity of sugar (a), quantity of pulp and cooking time (b), quantity of sugar and cooking time (c) on the total titratable acidity of jam obtained from *CARBAP K74* cultivated in Bansoa

and the pulp/sugar ratio on the quality of banana preserves. The values of the calculated R^2 statistic were 88.24 % and 82.39% respectively for jams produced using fruits harvested from Bansoa and Njombe. Thus the experimental values are equivalent to the predicted theoretical model values as the R^2 is higher than 75%, (Joglekar and May 1987).

Analysis of response surfaces

The 3D response surface plot is a graphical representation of the regression equation. It is plotted to understand the interaction of the variables and locate the optimal level of each variable for maximal response. Each response surface plotted for each response represents the different combinations of two test variables at one time while maintaining the other variable at the maximum level. Figure 1 is the response surface plot showing the effect of quantity of pulp and quantity of sugar (a), quantity of pulp and cooking time (b), quantity of sugar and cooking time (c) on total titratable acidity of jam obtained from *CARBAP K74* cultivated in Bansoa while Figure 2 is the response surface plot showing the effect of quantity of pulp and quantity of sugar (a), quantity of pulp and cooking time (b), quantity of sugar and cooking time (c) on total titratable acidity of jam obtained from *CARBAP K74*

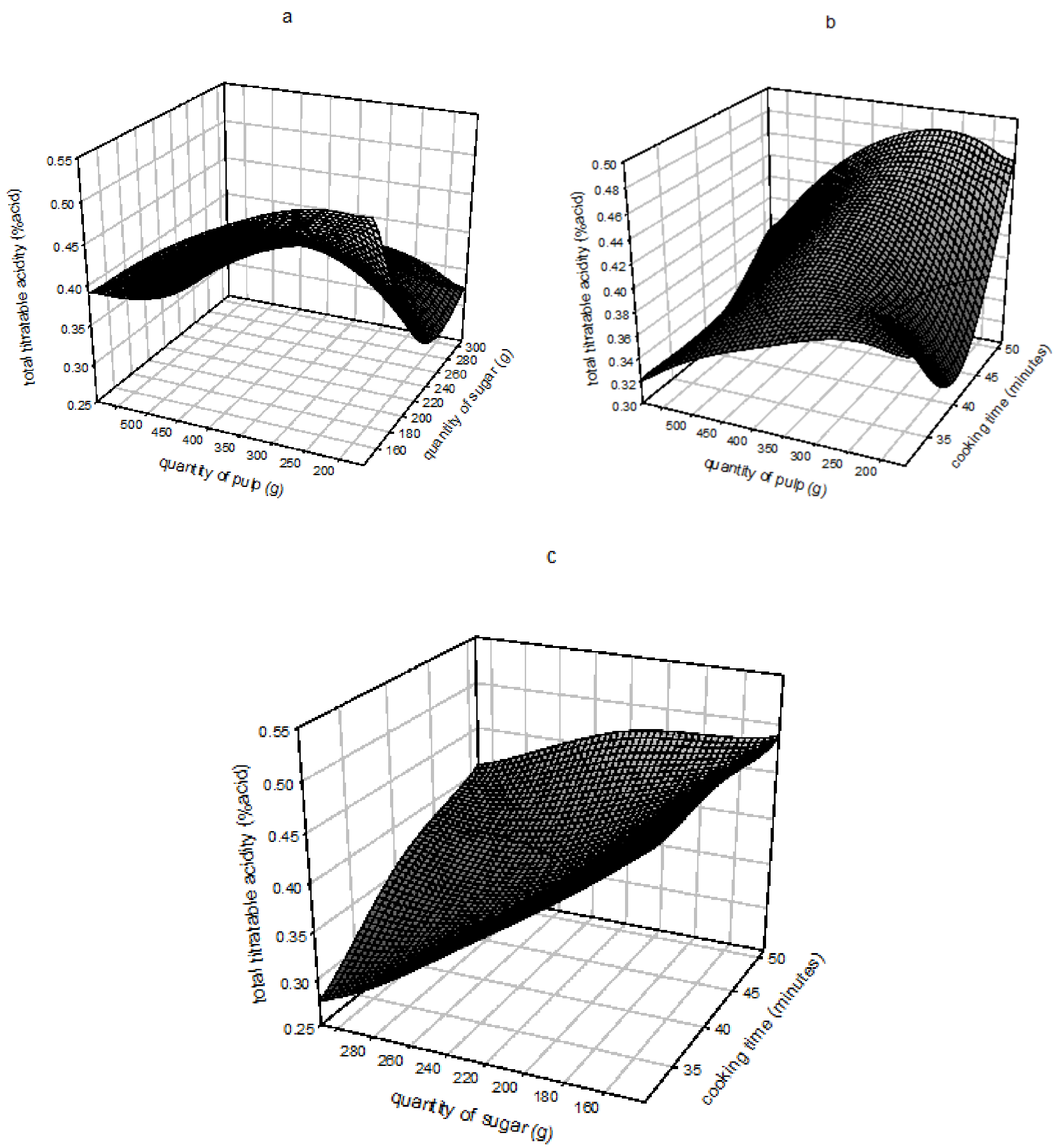

Figure 2: Response surface plots showing the effect of quantity of pulp and quantity of sugar (a), quantity of pulp and cooking time (b), quantity of sugar and cooking time (c) on the total titratable acidity of jam obtained from *CARBAP K74* cultivated in Njombe

cultivated in Njombe. The increase of *CARBAP K74* pulp had a negative influence on the total titratable acidity. This result is in contradiction with that obtained by Pereira et al. (2011) on a creamy banana marmalade cv. 'nanica' (*Musa cavendish*). This difference can be due to the *Musa* variety (plantain-like hybrid) as high quantity of pulp used needed a high volume of water which diluted the acidity of lime juice and pulps. Also, the quantity of sugar had a negative impact on the TTA as this is clear from the increasing sugar concentration compare to acid present. This result corroborate with that obtained by Pereira et al. (2011) and Khan et al. (2016). The positive influence of increasing cooking time on the TTA could be due to the fact that increasing cooking time leads to the dissociation of acid components by heat (Zakari et al., 2009).

Figure 3 shows the response surface plots showing the effect of quantity of pulp and quantity of sugar (a), quantity of pulp and cooking time (b) on the pH of jams obtained from *CARBAP K74* cultivated in Bansoa meanwhile the response surface plots showing the effect of quantity of

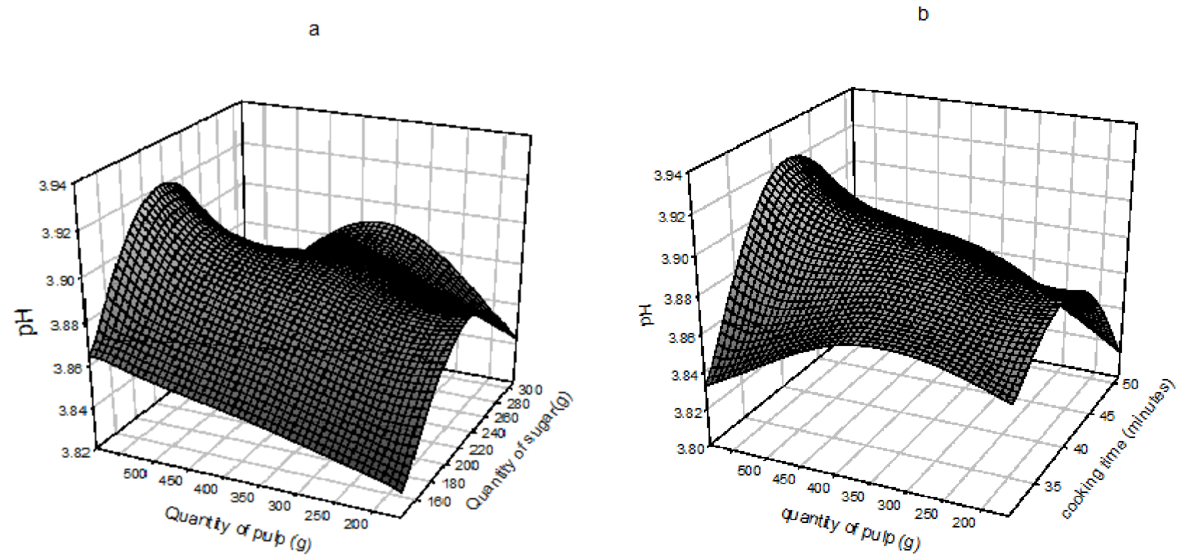

Figure 3: Response surface plots showing the effect of quantity of pulp and quantity of sugar (a), quantity of pulp and cooking time (b) on the pH of jam obtained from *CARBAP K74* of Bansoa

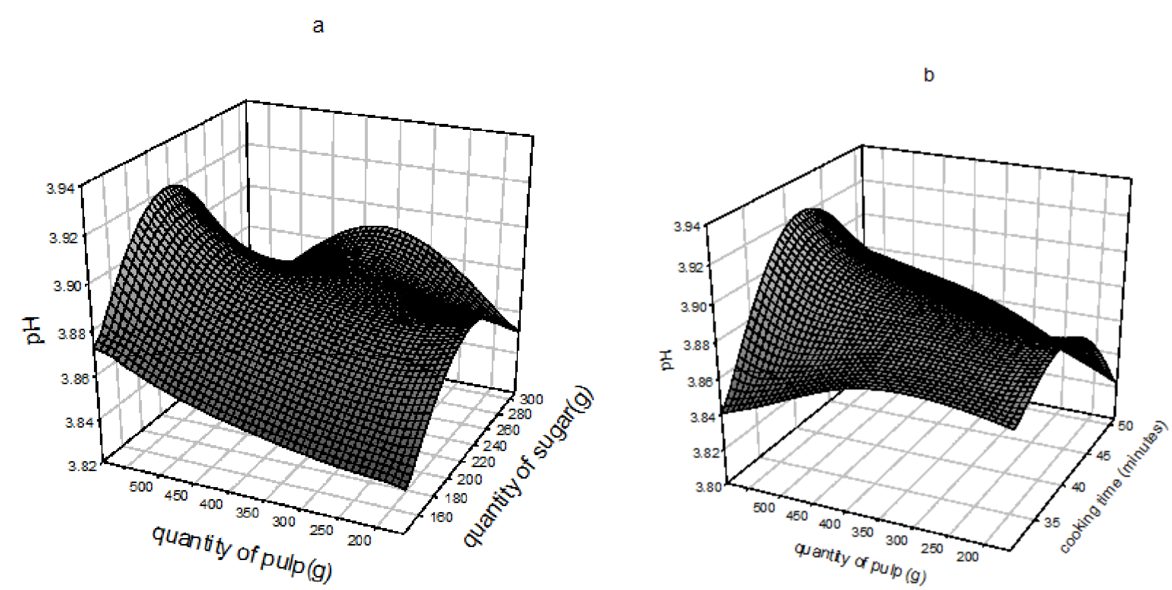

Figure 4: Response surface plots showing the effect of quantity of pulp and quantity of sugar (a), quantity of pulp and cooking time (b) on the pH of jam obtained from *CARBAP K74* of Njombe

pulp and quantity of sugar (a), quantity of pulp and cooking time (b) on the pH of jams derived from *CARBAP K74* cultivated in Njombe, is presented in Figure 4. Here, only effect of factors that had significant influenced on the responses was explained. The pH of jam produced using *CARBAP K74* fruit harvested either from Njombé or Bansoa increases as the quantity of pulp increase. This is due to the low titratable acidity of the *CARBAP K74* pulp, stage of maturation being one of the main factors that affect acidity (Hewage et al., 1995). Similar results were obtained by Igor et al. (2011).

Determination and experimental validation of optima conditions

The factor levels for the formulation that maximized the TTA = 0.55 % acid (Table 4) for jam processed with fruits from Bansoa were: cooking time (CT) = 47.25 min; quantity of sugar (QS) = 194 g and quantity of pulp (QP) of 338.9 g. The following values were recorded for jam formulated

Table 4. Predicted and experimental values under optimum conditions for maximum total titratable acidity and pH of both Njombe and Bansoa jam.

Origin of fruits for jam processing	Total titratable acidity (TTA)%acid		pH	
	Predicted values	Experimental values	Predicted values	Experimental values
Bansoa jam	0.55[a]	0.44[b]	3.91[a]	3.90[a]
Njombe jam	0.49[a]	0.40[a]	3.91[a]	4.20[a]

Means within each row with same superscripts are not significantly (P < 0.05) different

Table 5. Composition of optima jam formulations

	Coded sample formulations			
Ingredients	**ABC**	**MNO**	**DEF**	**JKL**
QP (g)	338.88	464.65	350.00	500.00
QS(g)	194.00	228.44	170.00	260.00
CT(min)	47.25	41.00	51.10	44.00
VL(ml)	135.60	185.90	140.00	200.00
VW(ml)	338.88	464.65	350.00	500.00

QP =quantity of pulp, QS= quantity of sugar, CT= cooking time, VL=volume of lime juice, VW=volume of water, ABC, MNO, DEF, and JKL are different jam formulations

with fruits harvested in Njombe: CT = 51.09 min, QP = 350 g and QS = 170 g with maximized TTA of 0.49 % acid. The maximized pH (3.91) from Bansoa jam was obtained from the factor levels CT = 41.0 min, QS = 228.44 g and QP = 464.65 g and that of Njombe jam (pH = 3.91) were as follows: CT=44.0 min, QP=500 g and QS=260 g (Table 4).

The experimental and predicted values did not vary significantly except for the TTA of Bansoa jam, which might be due to the fact that the raw material (*CARBAP K74* fruit*)* used was not at its appropriate maturation stage. These show that the models obtained can be used to obtain optimum jam formulation of good quality (Joglekar and May 1987).

The optimizing factor levels were coded for sensory evaluation and shelf-life study. The codes ABC and DEF were used for the factor level of total titratable acidity of jams produced with fruits harvested respectively from Bansoa and Njombé. MNO and JKL coded for maximizing factor levels for pH of jams derived from fruits collected in Bansoa and Njombe respectively. These factor levels were used due to the fact that, the total titratable acidity (TTA) values of the jam did not exceed 1% and that of pH was within the range of values reported by Garcia et al*.* (2002) for kiwi jam and orange marmalade where pH values were between 3.04 and 4.68.

Sensory evaluation

Table 5 shows the ingredient composition of the different optima jam formulations that were presented to the tasted made up of 35 females and 25 males. The predominant age ranges were 41-50 years (30%) and 23-40 years (25%). The four selected jams were evaluated using the average values of the scores obtained in the acceptance test during the sensory evaluation for the following attributes: color, taste, aroma, texture and global acceptability. The results showed significant differences with regard to color. The taste of formulation MNO differs from that of ABC, DEF and JKL formulations. Concerning the aroma attribute, MNO, ABC, JKL and DEF did not differ statistically. Formulation MNO reached an average of 6.8 and 7.3 for the attributes texture and global aspect respectively; this value differed from formulations ABC, DEF, and JKL (Figure 5). According to Sulaeman et al*.* (2002), for a product to be considered as accepted in terms of its sensorial properties, it is necessary that it obtains an acceptability index of at least 6 and in this case except formulation JKL whose colour score was less than 6, the MNO, ABC and DEF formulations obtained good acceptability for all of the analyzed attributes.

Shelf-life of optima jams formulations

Total titratable acidity (TTA)

The TTA is one of the physicochemical parameters which affect product quality, to a large extent as acidity protects against the development of microorganisms. Table 6 and 7 shows the effect of storage time on the TTA of samples stored at refrigerated and ambient temperature. The pronounced increase in the total titratable acidity (TTA) of samples stored at 25°C is due to high temperature at which the jams were stored enabling enzymatic reactions that cause the production of acid. Also the slight increase in the TTA as the storage period increases might be ascribed to the rise in the concentration of weakly ionized acid and their salts. Moreover, the synthesis of acids by the

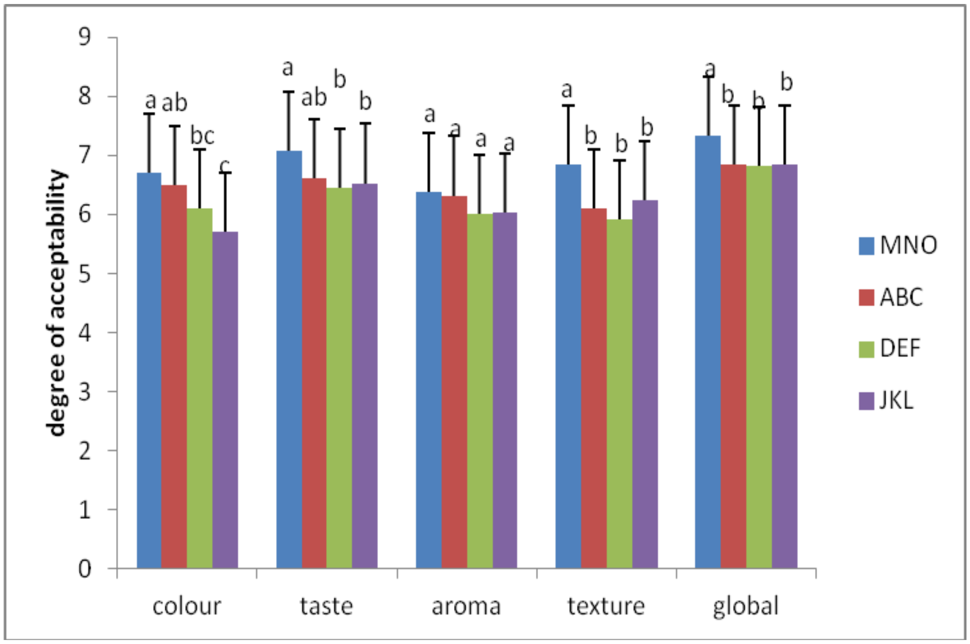

Figure 5: Sensory characteristics of optima jam formulations

MNO, ABC, JKL and DEF are codes for different jam formulations. Values bearing different superscripts differ significantly (p< 0.05)

Table 6. 1Effect of storage time on jam TTA (%acid) conserved at refrigerated temperature (4°C)

Fruit origin	Samples	Day1	Day7	Day14	Day21
Bansoa	ABC	0.34 ± 0.01^{a}	0.35 ± 0.00^{a}	0.36 ± 0.03^{a}	0.37 ± 0.02^{a}
	MNO	0.31 ± 0.01^{a}	0.33 ± 0.04^{a}	0.35 ± 0.01^{a}	0.38 ± 0.06^{a}
Njombe	DEF	0.44 ± 0.03^{a}	0.46 ± 0.03^{a}	0.49 ± 0.06^{a}	0.52 ± 0.08^{a}
	JKL	0.34 ± 0.00^{a}	0.346 ± 0.01^{a}	0.37 ± 0.00^{a}	0.35 ± 0.11^{a}

Mean ±standard deviations with thesame superscript letters in the same line are not significantly different at *P*< 0.05(Duncan's new multiple range test).

Table 2. Effect of storage time on jam TTA (%acid) conserved at ambient temperature (25°C)

Fruit origin	Samples	Day1	Day 7	Day 14	Day 21
	ABC	0.36 ± 0.01 ^{b}	0.36 ± 0.08 ^{b}	0.69 ± 0.06 ^{a}	0.76 ± 0.01 ^{a}
Bansoa	MNO	0.31 ± 0.01^{c}	0.31 ± 0.01^{c}	0.45 ± 0.04^{b}	0.55 ± 0.04^{a}
	DEF	0.43 ± 0.08 ^{b}	0.53 ± 0.04 ^{ab}	0.55 ± 0.04 ^{ab}	0.67 ± 0.11 ^{a}
Njombe	JKL	0.36 ± 0.03 ^{b}	0.39 ± 0.04 ^{ab}	0.48 ± 0.16 ^{ab}	0.70 ± 0.17 ^{a}

Mean ±standard deviations with different superscript letters in the same line are significantly different at *P*< 0.05(Duncan's new multiple range test).

degradation of polysaccharides and oxidation of sugars or break down of pectic substances to uronic acid cause the increase in TTA (Iqbal et al., 2001; Hussain et al., 2008). These results corroborate with data obtained by Touati et al., (2013). They reported a pronounced increase in the TTA of samples that were stored at a temperature of 25° C compared to those that were kept at 4° C.

pH

Tables 8 and 9 show the effect of storage time on the jam pH stored at refrigerated and ambient temperature respectively. The pH of jams stored at 4°C and 25°C experienced a decrease that was mostly significant for samples stored at room temperature as storage time

Table 3. Effect of storage time on jam pH conserved at refrigerated temperature (4°C)

Fruit origin	Samples	Day 1	Day 7	Day14	Day 21
Bansoa	ABC	4.00 ± 0.08 ^{a}	3.82 ± 0.02 ^{b}	3.73 ± 0.01 ^{b}	3.72 ± 0.01^{b}
	MNO	4.04 ±0.00 ^{a}	4.03 ± 0.00 ^{a}	4.03 ± 0.01 ^{a}	4.01 ± 0.00 ^{b}
Njombe	DEF	4.00 ± 0.00 ^{a}	3.90 ± 0.04 ^{a}	3.80 ±0.00 ^{b}	3.80 ± 0.01^{b}
	JKL	4.30 ± 0.02 ^{a}	4.20 ± 0.01 ^{a}	3.80 ± 0.03 ^{b}	3.77 ± 0.01 ^{c}

Mean ±standard deviations with different superscript letters in the same line are significantly different at $P< 0.05$ (Duncan's new multiple range test).

Table 4. Effect of storage time on jam pH conserved at ambient temperature (25°C)

Fruit origin	Samples	Day1	Day7	Day 14	Week 21
Bansoa	ABC	4.09 ± 0.00 ^{a}	3.83±0.01 ^{b}	3.62±0.00 ^{c}	3.53±0.01 ^{d}
	MNO	4.02 ± 0.01 ^{a}	3.89±0.01 ^{b}	3.72±0.03 ^{c}	3.66±0.00 ^{d}
Njombe	DEF	4.06 ± 0.00 ^{a}	4.02± 0.01 ^{a}	3.81 ±0.01 ^{a}	3.51 ± 0.20 ^{b}
	JKL	4.27 ± 0.01 ^{a}	4.08 ± 0.01 ^{a}	3.81 ± 0.01 ^{b}	3.78 ± 0.10 ^{b}

Mean ±standard deviations with different superscript letters in the same line are significantly different at $P< 0.05$ (Duncan's new multiple range test)

Table 5. Effect of storage time on jam TSS (°brix) conserved at refrigerated temperature (4°C)

Fruit origin	Samples	Day 1	Day 7	Day 14	Day 21
Bansoa	ABC	50.04 ± 1.18 ^{a}	49.20 ± 4.71 ^{a}	50.04 ±1.18 ^{a}	50.04 ±1.18^{a}
	MNO	41.70±1.17^{b}	43.36 ±1.18^{b}	44.20 ± 0.00^{ab}	46.7 ± 1.17^{a}
Njombe	DEF	54.20 ± 2.36^{a}	55.04 ± 1.18 ^{a}	55.04 ± 1.18 ^{a}	56.7 ± 1.17^{a}
	JKL	37.53 ± 0.00^{a}	38.36 ± 1.18^{a}	40.86 ± 1.35^{a}	42.54 ±1.70^{a}

Mean ±standard deviations with different superscript letters in the same line are significantly different at $P< 0.05$ (Duncan's new multiple range test).

Table 11. Effect of storage time on jam TSS (°brix) conserved at ambient temperature (25°C)

Fruit origin	Samples	Day1	Day7	Day 14	Day 21
Bansoa	ABC	49.20 ± 0.00^{a}	48.37 ±3.54^{a}	50.04 ± 5.89^{a}	55.04 ± 1.18^{a}
	MNO	42.53 ± 0.00^{a}	43.37 ±3.54^{a}	44.2 ± 4.71^{a}	46.7 ± 3.54^{a}
Njombe	DEF	49.20 ±1.18^{a}	56.70 ±1.17^{a}	57.53 ±0.00^{a}	58.36 ± 1.18 ^{a}
	JKL	37.53 ± 2.35^{b}	38.36 ± 1.18^{b}	41.7 ±1.17^{b}	47.54 ±1.35^{a}

Mean ±standard deviations with different superscript letters in the same line are significantly different at $P< 0.05$ (Duncan's new multiple range test).

increases. The most significant decrease was observed with the following formulations MNO, JKL and ABC stored at room temperature. The ascribed drop in pH for jams samples stored at 25°C was due to greater rate of carbohydrate fermentation as a result of favorable temperature for microbial activities (Fasoyiro et al., 2005; Ashaye et al., 2006). The deceasing pH with storage is proportional to TTA increase due to the formation of organic acids by ascorbic acid degradation and de-esterification of protein molecules (Patel et al., 2015). This same decreasing trend was reported by Nega (2016) who investigated jam development from selected mango varieties.

Total soluble solids (TSS)

The changing TSS during the conservation of samples stored at refrigerated and ambient temperature is shown in Table 10 and 11 respectively. The TSS of jam gradually increased with the storage time been significant only for sample MNO and JKL stored at refrigerated temperature. This increase in TSS during storage might be due to acid

Table 12. Effect of storage time on jam moisture content (%) kept at refrigerated temperature (4°C)

Fruit origin	**Samples**	**Day1**	**Day7**	**Day14**	**Day 21**
Bansoa	ABC	40.28 ± 1.27 [a]	38.25 ± 4.29 [a]	43.76 ± 4.42 [a]	40.90 ± 2.14 [a]
	MNO	49.20 ± 3.28 [a]	51.68 ± 0.70 [a]	53.84 ± 1.01 [a]	51.66 ± 3.49 [a]
Njombe	DEF	34.84 ± 2.14 [a]	39.96 ± 3.48 [a]	36.45 ± 0.44 [a]	38.02 ± 0.00[a]
	JKL	59.44 ±2.62 [b]	86.46 ± 1.31[a]	59.06± 0.00 [b]	64.15 ± 0.00[b]

Mean ±standard deviations with different superscript letters in the same line are significantly different at $P< 0.05$ (Duncan's new multiple range test).

Table 13. Effect of storage time on jam moisture content (%) conserved at ambient temperature (25°C)

Fruit origin	**Samples**	**Day1**	**Day7**	**Day14**	**Day21**
Bansoa	ABC	40.32 ±0.45 [b]	41.24 ±1.24 [b]	55.4 ±1.2 [a]	39.39± 0.00 [b]
	MNO	47.58 ±3.4 [a]	61.10 ±1.28 [a]	54.55 ±0.00 [a]	54.69 ± 2.21 [a]
Njombe	DEF	34.84 ±2.14 [a]	35.94 ±2.21 [a]	35.8±30.00 [a]	35.72±0.23 [a]
	JKL	60.34 ±1.35 [b]	64.63± 1.41 [a]	59.06 ±0.00 [b]	59.21 ±0.85 [b]

Mean ±standard deviations with different superscript letters in the same line are significantly different at $P< 0.05$ (Duncan's new multiple range test).

Table 14. Effect of storage time on jam dry matter content (%) conserved at refrigerated temperature (4°C)

Fruit origin	Samples	Day 1	Day7	Day14	Day21
Bansoa	ABC	59.72 ±1.27 [a]	61.76 ± 4.29 [a]	56.26 ± 4.42 [a]	59.1 ± 2.14 [a]
	MNO	52.42 ± 3.28 [a]	38.9 ±0.70 [b]	45.45 ±1.00 [c]	45.32 ± 2.49 [c]
Njombe	DEF	65.16 ± 2.14 [a]	60.04 ±3.48 [a]	63.55 ±0.44 [a]	61.98 ±0.00 [a]
	JKL	40.56 ± 2.6 [a]	13.54 ±1.31 [b]	40.94 ±0.0 [a]	35.85 ±0.00 [a]

Mean ±standard deviations with different superscript letters in the same line are significantly different at $P< 0.05$ (Duncan's new multiple range test).

hydrolysis of polysaccharides especially gums and pectin (Luh and Woodroof, 1975). This result corroborate with the conclusions investigations carried out by Safdar et al . (2012) on mango jam during the storage.

Moisture content (MC)

Table 12 and 13 show the effect of storage time on the moisture content of jam samples stored at refrigerated and ambient temperature. The formulation that had the least moisture content was DEF contrarily to JKL formulation that presented the highest MC. It has to be noted that the variation of moisture content did not follow any pattern due to the activity of microorganisms and their catabolic enzymes (Ashaye et al*.,* 2006). Similar fluctuation pattern was obtained by Ashaye and Adeleke (2009) on stored Roselle jam. During 21 days of storage, no significant difference was observed in relation to the MC of the four refrigerated formulations. Conservation at ambient temperature enables increase of MC of the four formulations with a significant effect on ABC and JKL.

Dry matter content (DMC)

Table 14 and 15 show the effect of storage time on the dry matter content of jam stored at refrigerated temperature and ambient temperature respectively. There was no significant difference in the DMC as the storage time increases, with sample DEF experiencing a greater DMC and JKL the smallest. There was also no definite pattern in the dry matter content of the jams. The fluctuations in the dry matter contents may also be due to the activity of microorganisms and their catabolic enzymes (Ashaye et al., 2006). Similar pattern was obtained by Ashaye and Adeleke. (2009) when working on quality attributes of stored Roselle jam.

Microbial analysis

Microbial analysis is an essential part of food safety. Confidence in the safety and integrity of the food supply is an important requirement for consumers. Tables 16 shows the microbiological examination (precisely yeast and

Table 15. Effect of storage time on jam dry matter content (%) conserved at ambient temperature (25°C)

Fruit Origin	Samples	Day 1	Day7	Day 14	Day 21
Bansoa	ABC	59.69 ± 0.44 [a]	58.76 ± 1.24 [a]	44.6 ± 1.20 [b]	60.61 ±0.00 [a]
	MNO	52.42 ± 3.42 [a]	38.9 ±1.23 [b]	45.45 ± 0.00 [c]	45.32 ±2.21 [c]
Njombe	DEF	65.16 ± 2.14 [a]	64.06 ± 2.21 [a]	64.17 ± 0.00 [a]	64.28 ± 0.23[a]
	JKL	39.67±1.36 [a]	35.37± 1.4 [b]	40.94 ±0.00 [a]	40.79± 0.85[a]

Mean ±standard deviations with different superscript letters in the same line are significantly different at $P< 0.05$ (Duncan's new multiple range test).

Table 16. Fungi load (CFU/g) of jam conserved at refrigerated (4°C) and ambient temperature (25°C)

	Refrigerated temperature (4°c)				Ambient temperature (25°C)			
	Bansoa		Njombe		Bansoa		Njombe	
Day	MNO($\times10^3$)	ABC($\times10^3$)	JKL($\times10^3$)	DEF($\times10^3$)	MNO($\times10^3$)	ABC($\times10^3$)	JKL($\times10^3$)	DEF($\times10^3$)
Day 1	0.032	0.032	0.009	0.059	0.573	0.064	0.009	0.800
Day 7	0.095	0.118	0.036	0.382	11.227	0.314	0.041	1.545
Day 14	0.191	0. 341	0.050	0.950	21.136	1.500	0.118	14.455
Day 21	0.268	0.486	0.068	1.091	25.318	2.500	3.123	18.864

Where MNO, ABC, JKL and DEF are codes for different jam formulations

moulds) of *CARBAP K74* jams stored for 21 days. We observed that samples stored at refrigerated temperature had lower microbial loads compared to those conserved at ambient temperature. During the storage of jam, samples stored at 4°C had a gradual increase in the microbial load compared to those kept at ambient temperature. Samples stored at refrigerated temperature had lower microbial loads compared to sample stored at ambient temperature due to appropriate temperature, and total titratable acidity content as well as high moisture content thus increasing the water activity which favours microbial growth. Also, as the storage time increases, the microbial growth in the samples increases. It was more pronounced in samples stored at ambient temperature as lower temperature reduce microbial growth. The least microbial growth was obtained from sample JKL, meanwhile the highest microbial load was observed on DEF formulation stored at 4°C during the 3 weeks of conservation. This could be explained by the fact that these samples had different quantities of ingredient such as high sugar and acid content in sample JKL which could not favour microbial growth. Also, during the 21 days of conservation, samples stored at refrigerated temperature had microbial growth ranged within 0.01×10^3 to 0.68×10^3 CFU/g (thus within acceptable limit for human consumption) (ICMSF, 1998). Concerning samples stored at ambient temperature, their consumption was safe only during the first week of storage. However, the presence of relative microbial loads during the first week of analysis in the samples could be a reflection of the quality of processing equipment, environment, packaging materials. Also, neither preservative nor pectin was used in the preparations.

Conclusion

The results indicate that the plantain-like hybrid (*CARBAP K74*) pulps produced at low and high altitudes in Cameroon are suitable for jam formulation. The quantity of sugar, the quantity of pulp and the cooking time significantly influenced total titratable acidity meanwhile pH was significantly influenced only by quantity of pulp. Also, sensory evaluation showed that 4 formulations were accepted by consumers. The MNO formulation made of pulps from highlands (Bansoa) exhibited the highest overall acceptability followed by ABC, JKL and lastly by DEF. The conservation study indicated that jam samples remained good for consumption when stored at temperature of 4° C within 21 days. After a week storage at 25° C, jam samples were not more suitable for consumption. It would thus be interesting to transfer the results of this study and the optimized jam protocol preparation to jam processors and consumers, in order to help the diversification banana and plantain uses, thus improving livelihoods of actors involved in banana and plantain production.

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Conflict of interests

The authors declare that they have no conflicting interests

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