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Cooking and drying processes optimization of *Pentadesma butyracea* kernels during butter production

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The cooking and the drying of the *Pentadesma butyracea* kernels are the main steps in the traditional method of extracting *P. butyracea* butter. In this work, the Response Surface Method with Central composite design was used to optimize the cooking and drying of *Pentadesma* kernels during *P. butyracea* butter production. The cooking and drying times, as well as the drying temperature of Pentadesma kernels are considered as independent factors. The moisture content of the Pentadesma kernels, the quantity, the acidity and the peroxyde values of extracted butter were the responses to be expected. The responses have been described using a second degree polynomial models which have been first tested and then used to explain 97.5, 80.7, 96.1 and 97%, of the variation of moisture content, quantity of butter, and acid and peroxide values, respectively. Increasing cooking time and drying temperature greatly reduced the free fatty acid values of the butter (<1%) and peroxide value (<1 meq/kg). The optimum cooking time (110 min), drying temperature (55°C) and drying time (72 h) could be used to get 52.92% of Pentadesma butter equivalent to the category 1 (with 0.62 meq/kg of peroxide and 0.28% of FFA content). Cooking and drying of Pendadesma kernels are important stages in the butter production. This work determined the optimum conditions of cooking and drying processes. These results could be used by *P. butyracea* butter processors to get good quality of Pentadesma butter and to improve extraction yield.

Key words: Forest galeries, *Pentadesma butyraceae*, cosmetic industry, temperature, shea butter, Pentadesma butter, Benin.

INTRODUTION

Pentadesma butyracea has been identified as species generally located in the dense forest with a large distribution area reaching from Sierra Leone to the Congo (Badoussi et al., 2014). *P. butyracea*, tallow tree (Clusiaceae) is a dense forest species with a height of about 20 m which is found in the center and the north of Benin in forest galleries and along water ways (Natta, 2003). The main product harvested from *P. butyracea* is its kernels which are processed into butter (Natta et al., 2010). This butter is traditionally used as frying oil,

moisturizing cream, soap, fire lightner and in herbal medicine (Sinsin and Sinadouwirou, 2003; Avocèvou-Ayisso et al., 2011; Natta et al., 2010; Badoussi et al., 2014). *Pentadesma* butter is a potential raw material in food and cosmetic industries (European Commission Directive, 2000; Tchobo et al., 2009; Badoussi et al., 2014; Ayégnon et al., 2015) which prefer a butter produced using traditional methods (biobutter) (Badoussi et al., 2014). In Benin, traditional processing of Pentadesma butter varies from one locality to another (Badoussi et al., 2014). In general, such process involves fruit harvesting, depulping, cooking, drying and butter extraction. In these systems, the butter extraction yields (25 to 26%) as well as quality (FFA > 3%) are relatively low, when referenced to similar shea butter standards (Badoussi et al., 2014). The most important quality criteria of shea butter are the free fatty acid (FFA) content and peroxide value (PV) (Nsogning Dongmo et al., 2014). The first quality grade butter (FFA < 1%, PV < 10 meq/KgO_2) is used by cosmetic industry, whereas the second quality grade butter (FFA < 3%; PV < 15 meq/Kg) is appropriate for the food industry (Lovett et al., 2012). Cooking and drying have been identified as the main pretreatment steps in the traditional processing of *P. butyracea* butter as they affect yield and the quality of the final product (Badoussi et al., 2015). Thus, it is important in optimizing cooking and drying processes during the *P. butyracea* butter production through temperature and time settings.

The typical optimization method involves one-factor-at-a time approach and keeping the other factors constant (Bas and Boyaci, 2007a). Such practices don't take into account interactive effects among the variables and, eventually, the complete effects of the parameters on the process (Bas and Boyaci, 2007b). Furthermore, One-factor optimization increases the number of required experiments for the research as well as the time and expenses reagents and materials (Bezerra et al., 2008). In the last three decades, Response Surface Methodology (RSM) has been used to correct these discrepancies (Liyana-Pathirana and Shahidi, 2005; Eren and Kaymak-Ertekin, 2007; Corzo et al., 2008; Wani et al., 2008; Changrue et al., 2008; Mestdagh et al., 2008; Shi et al., 2008; Altan et al., 2008; Erbay and Icier, 2009; Betiku et al., 2015). RSM analyses all the possible effects (Ebrahimpour et al., 2008), and generates a mathematical model which describes the chemical or biochemical processes (Bas and Boyaci, 2007a). Optimization studies on pretreatment process parameters for shea butter production using RSM have been reported (Womeni et al., 2006; Nde et al., 2012; Nsogning Dongmo et al., 2014).

This study aims therefore to point out the optimum conditions for cooking and drying Pentadesma kernels through the assessement of the combined effect of cooking time, drying temperature and drying time on the amount and the quality of the butter extracted RSM using the Central Composite Design (CCD).

MATERIALS AND METHODS

The *P. butyracea* fruits samples were collected from Bassila and Toucountounan parklands (Northern Benin) in the harvesting period (May 2014). The fruits were de-pulped to get the kernels which were used for the experimental design.

Experimental design

Pentadesma kernels pretreatment consisted of cooking and drying at different temperature and time. Samples of 1.2 kg each of Pentadesma kernels were put in 5 L of water and subjected to five cooking times (0, 30, 60, 90 and 120 min at 100°C). Each of the cooked kernels samples were dried at 40, 50, 60, 70 and 80°C in an oven with forced ventilation for 48, 60, 72, 84 and 96 h. The cooking and drying times as well as drying temperature were determined using the Central Composite Design (CCD) (Bas and Boyaci, 2007a). The CCD consisted of three independent variables: Cooking time (X_1: 0, 30, 60, 90 and 120 min), drying temperature (X_2: 40, 50, 60, 70 and 80°C) and drying time (X_3: 48, 60, 72, 84 and 96 h). These variables were used at five levels as described in Table 1. The levels of the different variables have been indicated by the results of a previous study (Badoussi et al., 2014). The moiture content (Y_1), the butter yield (Y_2) and the butter quality [acid content (Y_3) and peroxide value (Y_4)] were considered as responses. Second-order polynomial model equation (Equation 1) was defined and fitted to each response obained from the experimental data.

$$Y = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_{12} x_1 x_2 + b_{13} x_1 x_3 + b_{23} x_{23} + b_{11} x_1^2 + b_{22} x_2^2 + b_{33} x_3^2 \quad (1)$$

Y indicates the estimated response, b_0, b_1, b_2, b_3, b_{11}, b_{22}, b_{33}, b_{12}, b_{13} and b_{23} are constant coefficients where b_0 is a constant, b_1, b_2 and b_3 are coefficients for linear terms, b_{11}, b_{22} and b_{33} are coefficients for quadratic terms, and b_{12}, b_{13} and b_{23} are the interaction coefficients. x_1, x_2 and x_3 are the coded values of the independent variables of cooking time, drying temperature, and drying time, respectively. The coded values are obtained by transforming the reals values using the following relation:

$$xi = \frac{Xi - X0i}{\Delta X} \quad (2)$$

Where, Xi is the natural variable (or real value), X_{0i} is the central value of natural variable i, ΔX is the increment.

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Abbreviations: FFA, Free fatty acid; **RSM,** response surface methodology; **CCD,** central composite design.

Table 1. Responses values in relation with their regression coefficients and relative standard errors.

Experimental matrix							Responses			
Coded values				Real values						
N°	x_1	x_2	x_3	X_1 (min)	X_2 (°C)	X_3 (h)	Y_1 (%)	Y_2 (%)	Y_3 (%)	Y_4 (meq/kg)
01	1	-1	1	120	40	96	8.54	54.80	1.28	1.06
02	1	1	-1	120	80	48	4.44	45.85	0.56	2.91
03	1	-1	-1	120	40	48	12.70	57.39	2.12	2.17
04	-1	1	-1	0	80	48	7.78	47.26	0.66	4.42
05	0	0	0	60	60	72	7.45	44.55	0.33	1.25
06	-1	-1	1	0	40	96	16.10	49.20	2.74	7.93
07	1	1	1	120	80	96	2.77	43.02	0.46	2.18
08	-1	1	1	0	80	96	3.26	44.43	0.37	2.50
09	-1	-1	-1	0	40	48	28.32	15.62	3.86	12.80
10	0	0	0	60	60	72	6.90	47.63	0.35	1.34
11	0	0	0	60	60	72	7.64	45.31	0.32	1.28
12	0	0,5	0	60	70	72	6.28	46.23	0.61	0.99
13	0	0	0.5	60	60	84	6.90	45.27	0.62	0.78
14	0	-0.5	0	60	50	72	9.64	50.59	0.74	2.98
15	0	0	-0.5	60	60	60	6.27	44.20	0.30	0.98
16	-0.5	0	0	30	60	72	8.13	50.44	0.40	1.45
17	0.5	0	0	90	60	72	6.63	45.42	0.44	1.67

x1, Coded value of cooking time; x2, coded value of drying temperature; x3, coded value of drying time; X1, X2 and X3, real values of cooking time, drying temperature and drying temperature respectively; Y_1, moisture content; Y_2,extraction yield; Y_3 acid content; Y_4, Peroxide value.

Kernels moisture content

Kernel were crushed or powded using smaller chips. About 10 g of the ground kernels (m_1) was weighed into a previously weighed crucible, (m_0) and dried in an oven at 105 °C for 24 h to constant mass according to AFNOR (1993) and Nde et al. (2012). Each experiment was carried out in triplicate. % Moisture content (wb)

$$Y1 = \frac{\text{loss in weight}}{\text{sample weight}} \times 100 \quad (3)$$

Extraction and quantitative evaluation of Pentadesma butter

For this analysis, about 10 g of the pre-treated Pentadesma kernels samples were weighed into a thimble and inserted into the column of the sohxlet extractor according to AFNOR (1993). To get Pentadesma butter, oil was first extracted for 7 h using hexane in a soxhlet apparatus into a previously cleaned, dried and weighed extraction flask. The solvent was evaporated on a rotary evaporator and the flask containing the recovered oil was dried at 65°C, to drive away the residual solvent. Then, the dried oil was cooled at room temperature (25 to 30°C) to get Pentadesma butter. The butter extraction yield (Y2) was obtained by difference and expressed as a percent of the mass of the sample taken for analysis on dry basis according to the relation.

$$Y2\ (\%) = \frac{Pentadesma\ buter\ \text{weight obtained}}{dry\ matter\ weight\ of\ Pentadesma\ kernel\ used} \times 100 \quad (4)$$

Pentadesma butter quality assessment

Free fatty acid content

One gram of the Pentadesma butter sample was weighed into a conical flask and first dissolved in 150 ml of 1/1 (v/v) of 95% (v/v) ethanol and dietyhlether mixture. The mixture was then titrated with shaking against the ethanolic potassium hydroxide solution (AFNOR, 1993). The percentage of free fatty acids (FFA), is Y3, expressed as % of oleic acid, as followed:

$$Y3 = \frac{N \times V \times 282}{m \times 1000} \quad (5)\ (AFNOR, 1993)$$

Where, V, is the volume (ml) of the standard potassium hydroxide solution used; N, is the exact normality of standard potassium hydroxide and m, sample weight.

Peroxide value

Ten (10) ml of chloroform was added to about 2 g of butter and homogenized to rapidly dissolve the sample. Fifteen (15) millilitres of acetic acid and 1 ml of potassium iodide were successively added. The flask was corked and agitated for about a minute and kept in the dark for about 5 min. At this stage, about 75 ml of distilled water was added. The solution was titrated against sodium thiosulphate solution using starch indicator. The volume (V) was then noted. A blank test (without the sample) was carried out

through the same procedure (AFNOR, 1993; Bup Nde et al., 2012). The volume (V0) was then noted. The peroxide value (Y4) in milliequivalents per kilogram was given by:

$$Y4 = \frac{1000 \times N \times (V - V0)}{m} \quad (6)$$

Statistical analysis

Models validation

Coefficient of determination (r^2) and absolute average deviation percentage (AAD) between experimental and calculated results were the two criteria used to evaluate the validity of the models (Bas and Boyacı, 2007a; Betiku et al., 2015). A model was considered valid if $R^2 > 0.7$ and/or AAD < 10% (Bup Nde et al., 2012). The coefficients of determination were obtained using multiple linear regression analysis carried out on the results using MINITAB (Version 14) software, while AAD was calculated from as followed:

$$\mathbf{ADD}(\%) = \frac{\mathbf{100}}{\mathbf{n}} \sum_{\mathbf{n=1}}^{\mathbf{n}} \left| \frac{\mathbf{Yi,exp - Yi,cal}}{\mathbf{Yexp}} \right| \quad (7)$$

Where, Yi, exp and Yi, cal are the experimental and calculated responses, respectively, and n is the number of experimental run.

Optimisation of kernel cooking and drying processes during butter production

The optimisation response variables were performed using response optimizer option of MINITAB (Version 14) with the desirability function technique. Experimental data for the responses are considered as an independent set of experiment following the optimum conditions. The experimental value was compared with the predicted from the optimised model by calculating the percentage error (Equation 8) to determine the efficiency of the cooking and drying processes and response surface models. The percentage error (PE) which is lower than 10% indicates a good fit (Kek et al., 2014).

$$\boldsymbol{PE}(\%) = \left(\frac{\boldsymbol{mexp - mpre}}{\boldsymbol{mexp}} \right) \times \mathbf{100} \quad (8)$$

Where, mexp is experimental value and mpre is predicted value

RESULTS AND DISCUSSION

Predicted models for the cooking and drying processes of Pentadesma kernels

Application of RSM to cooking and drying conditions for Pentadesma butter production released responses which r^2 value is greater than 70% and/or ADD less than 10%, satisfying valitidy conditions suggested by Bup Nde et al. (2015). The models for the responses were therefore judged valid to be used in the description of the cooking and drying process for butter extraction. Plots of interaction effects of factors were generated from the validated equations and used together with p-values and model coefficients to evaluate the effect of the independent factors on the magnitude of the responses studied.

Effect of cooking time, drying temperature and drying time on *Pentadesma* kernels moisture content

P. butyracea kernels moisture content (MC) obtained ranged from 2.77 to 28.32% (Table 1). It was significantly and negatively related to the linear effects of cooking time ($P < 0.01$), drying temperature ($P < 0.01$) and drying time ($P < 0.01$) but was significantly and positively related to the interaction effect of cooking time and drying temperature ($P < 0.001$) and cooking time and drying time ($P < 0.001$). The model has high coefficient of determination r^2 (97.5%) (Table 2). Figure 1 shows the surface plots for the effect of the independent variables on the moisture content. From Figure 1A, it is observed that when the drying time (Dt) was kept constant at the central point, the moisture content decreased steadily to a minimum point with increasing cooking time (CT) and drying temperature (DT). The similar observation was noted when the drying temperature was kept constant at the central point (Figure 1B). When the cooking time (CT) increases, the moisture content decreased at constant drying temperature and time. For example, at 40°C and 48 h of drying, the moisture content was 28.32% in uncooked kernels but decreased to 12.27% after 120 min of cooking. Also, when the drying temperature (DT) was kept constant at the central point for 48 h (Dt) (Figure 1a), the moisture content of the kernel was nearly 15% in uncooked kernels but less than 5% in kernels cooking for 120 min. This could be due to the desorganisation of the structure of Pentadesma kernels which is favorable to the evaporation of water under the effect of heat. It has been reported that cooked kernels of *P. butyracea* have a longitudinal slit (Aissi et al., 2011). The drying time and temperature necessary to bring the moisture content of kernels to 7% could be reduced by increasing the cooking time. Such process would reduce the drying time; the moisture content of the kernels is below 7% after the cooking process. Nsogning Dongmo et al. (2014) studying the infuence of cooking and drying parameters on shea nut, reported that the cooking time did not influence the moisture content of shea nuts. This could be due to the presence of shell, which reduces the effect of the cooking. However, Aculey et al. (2012) reported that the ease of cracking and separation of the shea kernels from the shells depended upon the duration of cooking. Studies on the structure of shea kernels under scanning electron microscopy showed a pronounced effect of cooking on the sorption of water onto shea nut kernels which have been attributed to the loss of components containing water-binding hydrophilic

Table 2. Model constants, p-values, r^2 and ADD values for the responses studied.

Parameter	Y_1 (%w.b.)		Y_2 (% d.b)		Y_3 (%)		Y_4 (meq/kg)	
	Coefficient	Pvalue	Coefficient	P value	Coefficient	P value	Coefficient	Pvalue
b_0	7.2948	0.000	45.6810	0.000	0.36210	0.092	1.24741	0.043
b_1	-3.2654	0.001	4.9458	0.060	-0.37478	0.015	-2.26118	0.000
b_2	-5.7739	0.000	0.1614	0.942	-0.94276	0.000	-1.52294	0.002
b_3	-2.6171	0.003	3.0432	0.204	-0.25875	0.059	-1.02706	0.014
b_{11}	1.2883	0.732	3.6908	0.808	0.00164	0.998	1.41719	0.514
b_{22}	3.6162	0.352	5.6184	0.712	1.01563	0.229	3.11719	0.178
b_{33}	-1.8975	0.615	-9.0913	0.555	0.16833	0.832	-1.30281	0.547
b_1b_2	2.4179	0.004	-6.2703	0.029	0.39789	0.013	1.95875	0.001
b_1b_3	1.3636	0.046	-4.5212	0.086	0.05702	0.637	0.61875	0.092
b_2b_3	1.2740	0.057	-4.5814	0.082	0.19821	0.135	1.346	0.227
r^2 (%)	97.5		80.7		96.1		97.0	
ADD (%)	1.85		0.65		23.96		46.16	

w.b. , wet basis ;d.b.,dry basis ; ADD, absolute average deviation percentage; Y_1, moisture content; Y_2,extraction yield; Y_3, free fatty acid content; Y_4, Peroxide value.

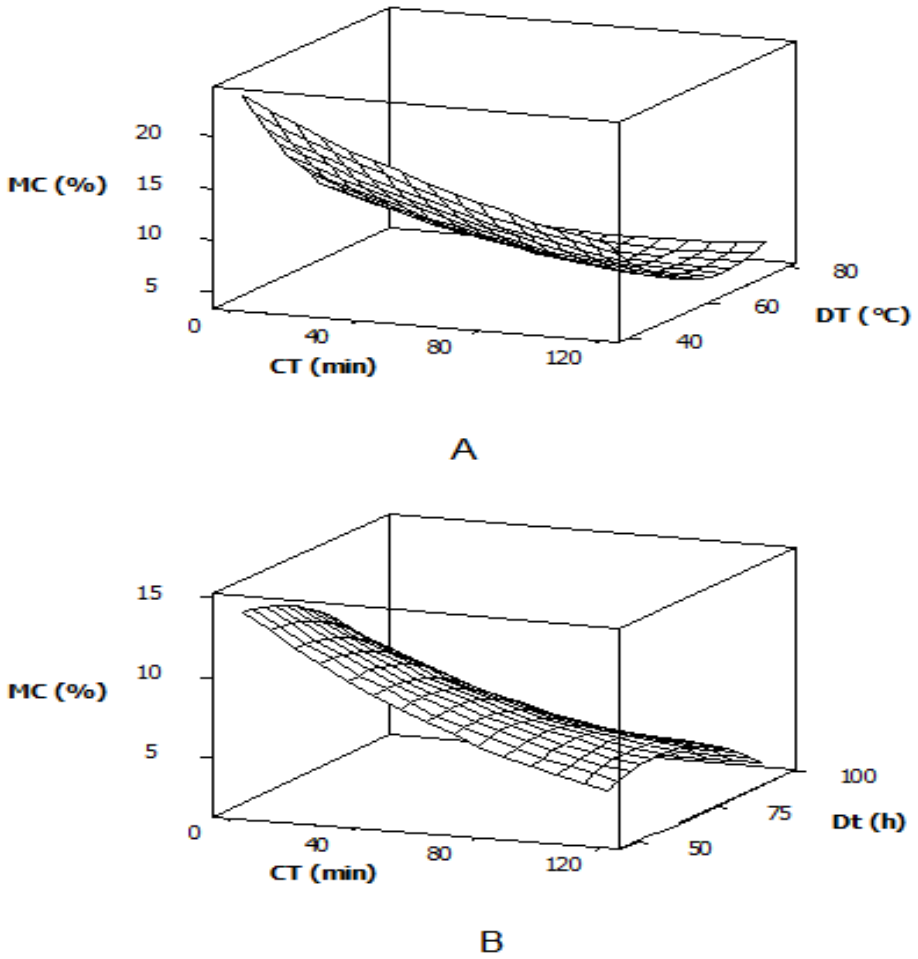

Figure 1. Effect of cooking time and drying temperature time (drying time = 72 h) (A) and cooking time and drying time (drying temperature = 60°C) (B) on the moisture content of Pentadesma kernels. MC, Moisture content; CT, cooking time; DT, drying temperature; Dt, drying time.

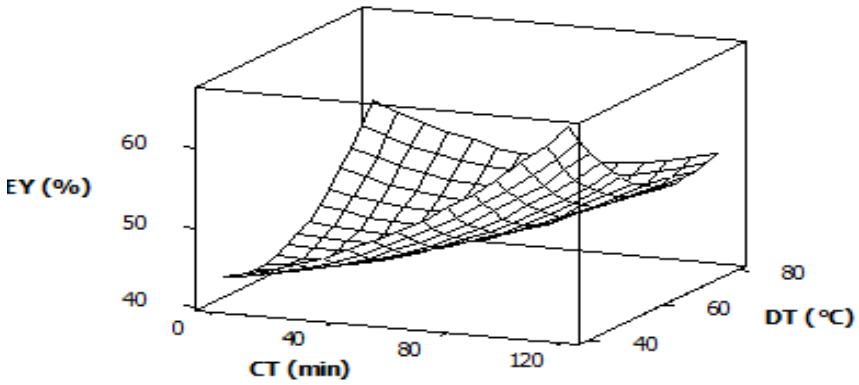

Figure 2. Effect of cooking time and drying temperature time of Pentadesma butter extraction yield (drying time = 72 h). EY, Extraction yield; CT, cooking time; DT, drying temperature.

groups like proteins, carbohydrates, and catechins during cooking (Bup Nde et al., 2013).

Effect of cooking time, drying temperature and drying time of kernels on butter extraction yield

The influence of cooking time, drying temperature and drying time on butter yield of *Pentadesma* kernels is presented in Figure 2. The linear terms (b0, b1, b2, b3) and the quadratic terms of cooking time and drying temperature showed a positive effect while the quadratic term of drying time showed a negative effect on the butter extraction yield extracted from *Pentadesma* kernels (Table 2). The effects of the interaction of cooking time with drying temperature, cooking time with drying time and drying time and drying temperature on the butter extraction yield were negative ($P < 0.05$). When the drying time and drying temperature were each held constant at the central point, the butter extraction yield increased with time until it reached a maximum after 120 min (Figure 2). Olaniyan (2002), Aviara et al. (2005), Womeni et al. (2006) and Honfo et al. (2013) stated that the boiling of shea nuts is necessary to allow efficient fat extraction. Indeed, cooking coagulates proteins thereby allow free space for butter diffusion and increasing butter extraction yield as cooking time increases (Bup Nde et al., 2012). Similar effect was observed at high drying temperature. Heating has the ability to break open cell wall membranes, decrease oil viscosity and increase solvency power thereby facilitating the oil extraction process (Nde et al., 2014). However, at low drying temperature and long cooking time, the extraction yield increased as well.

Effect of cooking time, drying temperature and drying time of kernels on acid content of the extracted Pentadesma butter

The free fatty acid (FFA) content of extracted butter ranged from 0.3 to 3.9%. Surface plots and the model constants for FFA content are shown in Figure 3 and Table 2, respectively. FFA content was significantly and negatively related to the linear effects of cooking time ($P < 0.05$) and drying temperature ($P < 0.01$) but was significantly and positively related to the interaction effect of cooking time and drying temperature ($P < 0.05$). The quadratic terms were not significant. Less than 50 min cooking time and below 50°C drying temperature are conditions that leads to the most acids butters (Figure 3). Less than 50 min of cooking appear to be insufficient to completely inactivate lipases naturally present in the Pentadesma kernel. Moreover, a lower drying temperature near 50°C is insufficient to denature lipases and inhibit fungal flora colonisatrice (Woméni et al., 2006). The decrease in FFA content with increasing cooking time and increasing drying temperature is probably linked to the denaturing of lipases (Nsogning Dongmo et al., 2014). Norris (1982) stated that the lipases which are naturally present in shea kernels catalyse the hydrolysis of its fats to liberate free fatty acids.

Fruit lipases are thermolabile and can be denatured at 100°C after 10 min (Ladurelle, 1984). Hence, the denaturing of these enzymes at higher cooking time and drying temperature probably slowed down hydrolysis. Overall, the FFA content of Pentadesma butter remains below 4% maximum acidity recommended by Codex (1992) and close to 0.3% for the shea butter required in cosmetic (Defez, 1992).

Effect of cooking time, drying temperature and drying time of kernels on peroxide value of the extracted Pentadesma butter

The peroxide value was significantly but negatively related to the linear effect of cooking time ($P < 0.001$), drying temperature ($P < 0.001$) and drying time ($P < 0.05$) and positively to the interaction effect of cooking time and

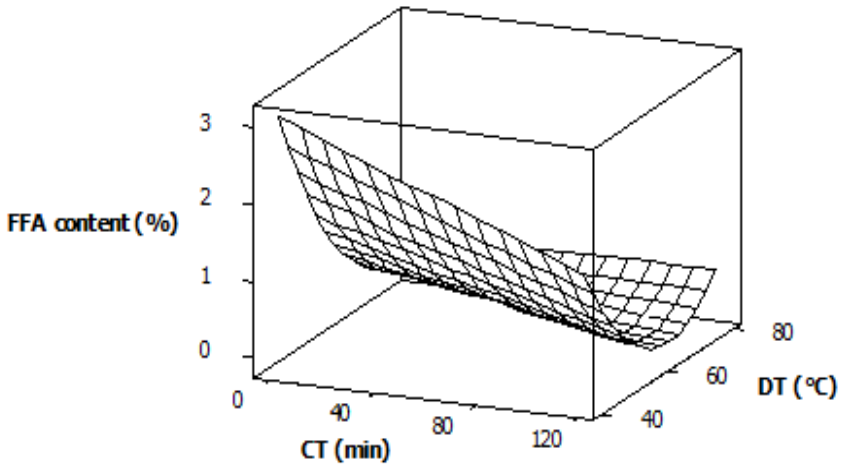

Figure 3. Effect of cooking time and drying temperature on free fatty acid content of Pentadesma butter (drying time = 72 h). FFA, Free fatty acid; CT, cooking time; DT, drying temperature.

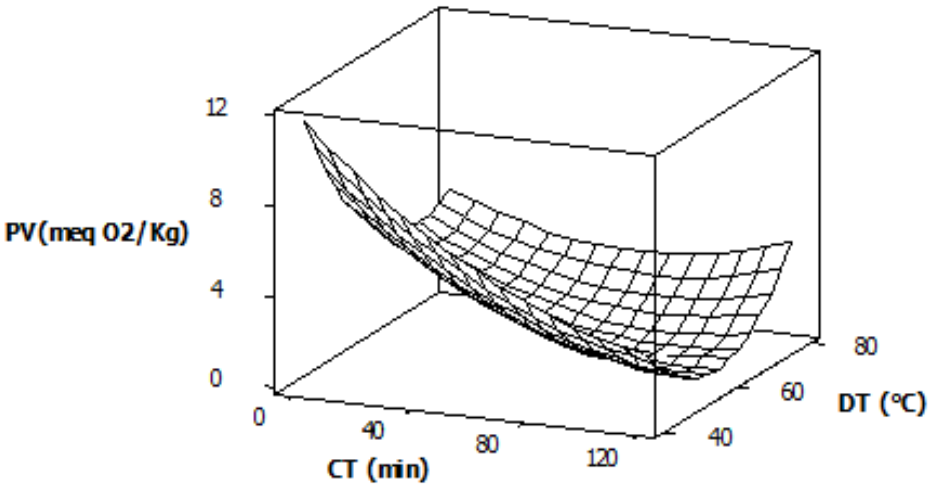

Figure 4. Effect of cooking time and drying temperature on peroxide value (meqO_2/Kg) of Pentadesma butter (drying time = 72 h). PV, Peroxide value; CT, Cooking time; DT, Drying temperature.

drying temperature ($P < 0.05$). The peroxide values obtained ranged from 0.78 to 12.80 meq/Kg. Some values were lower than those reported by other researchers on shea butter (Megnagnou et al. 2007; Olaniyan and Oje, 2007; Bup Nde et al., 2012). At constant drying time (Figure 4), the peroxide value decreased to a value less than 1 meq/kg at 40 to 60°C and then rose again to values higher than 6 meq/kg. Lipid oxidation is rapid at high moistures and water activity, as are all reactions, but unlike other degradation reactions, lipid oxidation is just as rapid in very dry systems (Schaich et al., 2013). With the drying temperature held constant, the peroxide value decreased steadily as the cooking time increased. However, Nsogning Dongmo et al. (2014) reported that the peroxide value increased steadily as cooking and drying temperature, and cooking time of shea kernel increased. The rise in the peroxide value may be due to the dissolution of water soluble anti-oxidants such as the monomers and polymers of catechins during prolonged cooking time (130 to 180 min) (Nde et al., 2012). Overall, the peroxide values of *Pentadesma* butter remains below 10 meq/kg and respect the quality criterion unrefined shea butter of first choice (Lovett et al., 2012).

Optimal cooking time, drying temperature and drying time of kernels for quantitavily and qualitatively production of Pendatesma butter

Optimum to cooking and drying processes conditions of *P. butyracea* kernels were determined by specifying the

Table 3. Process variables, responses optimisation, desirability, and experimental value for the responses at optimum conditions.

Variables	Goal	Lower	Target	Upper	Predicted	Desirability	Experimental
Factors						1	
X1 (min)	In range	0	In range	120	112.58	1	110
X2 (°C)	In range	40°C	In range	80	53.91	1	55
X3 (h)	In range	48	In range	96	72.70	1	72
Responses							
Y1 (%w.b.)	minimize	7	7	8	6.82	1	6.90±0.59
Y2 (%d.b.)	maximize	50	55	55	55	1	52.95±1.35
Y3 (%)	minimize	0.3	0.3	1	0.3	1	0.28±0.02
Y4 (meq/kg)	minimize	1	1	10	0.56	1	0.62±0.06

X1, X2 and X3 are optimum values of cooking time, drying temperature and drying temperature respectively; Y1, Y2, Y3 and Y4 moisture content, extraction yield, acid content and peroxide value obtained at optimum condition.

goal for each response. It was targeted to obtain minimum water content, acid value, peroxide value and maximum butter extraction yield (Table 3). The quality attributes of first quality shea butter reported in Lovett et al. (2012) and Defez (1992) were used as reference. The composite desirability value of the optimum solution was 1.0 for the optimised cooking time 112.58 min, drying temperature of 53.91°C and drying time of 72.70 h (Table 3). The adequacy of the statistical model equations for predicting optimal response attributes were tested by Cooking time 110 min, drying température 55°C and drying time 72 h. Table 3 shows the model verification results. The percentage errors from Equation 8 for water content, butter extraction yield, acid value and peroxyde value are 1.15, 3.87, 7.14 and 9.68%. The predicted values were found in the range of experimental value. Acid value and peroxide value obtained were low compared to values of 13.34% and 0.74 meqO_2/kg given by Ayégnon et al. (2015) for *P. butyracea* butter produced by cottage enterprises in Benin and consistent with the standards of the shea butter of first quality (Defez, 1992; Lovett et al., 2012). These values are also lower than those of shea butter extracted in optimal conditions (Womeni et al., 2006; Bup Nde et al., 2012; Nsogning Dongmo et al., 2014). This could be explained by the fact that *P butyracea* kernels do not have shells. *P. butyracea* butter obtained in optimal conditions could be used not only in food and cosmetics industries but also for biodiesel production for the low free fatty acid content (Betiku et al., 2015).

Conclusion

This study has shown the applicability of RSM selecting extraction conditions for *P. butyracea* butter from its kernels. This approach has not only indicated combination of maximum butter yield through solvent extraction, but has also suggested control points that guaranteed the fulfillment of the properties requirements of the butter. The optimum values for yield, acid value and peroxide value from the surface plot was establilished. The validation experiments and their accompany quality characteristics were not significantly different from the simulated values. These results indicate that controlled cooking and drying of *P. butyracea* kernels can lead to the production of butter of desired quality at semi or industrial scale.

Conflict of interests

The authors did not declare any conflict of interest.

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