ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 5, Issue, 02, pp. 212-218, February, 2013

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

Effects of added Maize Flour on Physicomechanical Properties of Benin Patties made of Defatted dough of Groundnut Seeds "*Arachis hypogaea*"

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ARTICLE INFO

Article History:
Received 14th November, 2012
Received in revised form
24th December, 2012
Accepted 20th January, 2013
Published online 14th February, 2013

Key words:
Groundnuts; Dough;
Patties; Flour;
Expansion ratio,
Break strength,
Behavior.

ABSTRACT

The promotion of groundnut sector in Benin required not only the usual seeds oil extraction, but also high-priced exploitation of rejected seeds cake. This residue entered manufacture of patties locally called kluiklui particularly prized by populations. Those fritters/patties were obtained at the end of frying of defatted dough of crushed seeds. The mastery of qualitative characteristics and industrial parameters for manufacturing groundnut patties ought to expand consumption range at regional and international levels generating more incomes throughout increasing foreign exchanges. This paper dealt with exploration and determination of patties physical and mechanical characteristics linked to crunchy descriptors and induced effects of adding crude maize flour to defatted groundnut cake. Obtained results showed that, incorporating maize flour at reasonable percentages 5 to 10% (mass basis) rose in patties crunchy quality improvement. However, recorded high value of remnant moisture 8.74-13.55% (dry basis) disclosed that the fried-patties required further drying. Moreover, the low break strength of maize mixed patties well confirmed their crusty behavior compared with those ensuing from pure defatted cake. Combining the previous two properties obviously indicated that actual conditions of patties production were unfavorable neither to a sustainable conservation nor to handling and transport.

INTRODUCTION

Groundnut patties or peanut donuts, made on basis of crushed seeds cake, were recognized as crunchy food and well prized products in Benin. They were also affectionate in border countries of Benin like Niger, Nigeria, Burkina Faso, Togo and non-borders in Africa, Europe and Asia, because of Benin peoples' dynamics and mobility. A tropical plant, found in 17th century in Latin America (the Caribbean), groundnut also called peanut had been noticed in Africa in 18th when botanist Linné (1753) gave it the well known scientific name "*Arachis hypogaea*" (FAO, 2010; Maiti and Wesche-Ebeling, 2002). It's spread worldwide, mainly in USA where consumption of seeds was relatively high, about 3.2kg/year/person (Rancé *et al.*, 1999) but not as higher as in Benin with 12kg/year/person (FAO, 2002). Important source of proteins, fat, vitamins and minerals (Brink and Belay, 2006; Knoden *et al*, 2003), groundnut plant grew on almost all the Benin territory, particularly in its predilection areas: Atacora, Couffo, Zou and Collines Departments (FAO, 2002; Ahoyo, 2001). Matured seed of groundnut contained (Souci *et al.*, 2008; Van der Vossen and Mkamilo, 2007) about 47% by weight of fats, 26% proteins and 20-25% for carbohydrates (cellulose, hemicelluloses 8-10% by weight, 4% starch and 10-12% sugars). Improper storage of groundnut seeds generated development of toxic substances, chiefly aflatoxins difficult to eliminate (FAO, 2010; Boulay *et al.*, 2008-b). Groundnut was fingered as an allergen product (Pansare and Kamat, 2009-b; King *et al.*, 2009; Boulay *et al.*, 2008-b). High relative humidity was the major cause of the seeds decay. At 65 to 70 % relative humidity, the moisture content of groundnut seeds should be 8 %. However, the Standard Codex 200-1995 indicated maximal values of 10 % for not shelled groundnut pods and 9 % for nude seeds. Lower temperatures and in hulls preservation of groundnut were known as advantageous factors for a sustainable conservation (Knoden *et al.*, 2003). Literature was relatively abundant on groundnuts production and marketing in classical forms as extracted oil, not shelled and dried seeds, roasted seeds (Desai *et al.*, 1999; Pesquet, 1996; Griffin, 1990; Cornelius and Colld, 1975; Gillier and Silvestre, 1969). On the contrary, very few papers were devoted to groundnut seeds conversion into patties and subsequent commercialization (Adjadja, 2004). However, none had yet addressed this target crunchy quality of such patties called "kluiklui" in Benin. Nevertheless, the groundnut production was estimated to be 130,000 tons (MAEP, 2010; 2008). More than half of this crop was committed to craft transformation into oil and patties. The remaining harvest was sold mostly in urban centers (Adjadja, 2004; MAEP, 1996; Asiedu, 1991). Traditional processing of groundnut seeds, that preceded patties production, was very tedious because all of its steps were still almost rudimentary, principally the seeds grinding and oil extraction. While many efforts have been made elsewhere for industrialization of groundnut oil-extraction and manufacture of the animal flours (Sidibe, 2005; Freud, 1997; Pattee and Young, 1995; Copans, 1980; Cornelius and Colld, 1975), no significant improvement was discernible in processing of the seeds remnant defatted dough into crunchy patties and their wrapping (FAO, 2002; Ogouniyi, 1997). The present study aims to identify and evaluate some characteristic parameters that can well describing different (variant) formulations of Beninese peanut patties in relation with their crunchy quality.

MATERIALS AND METHODS

Raw Material: Groundnut Seeds

The groundnut seeds used in all conducted experiments in this study, about 50 kg, were acquired at Bohicon market (Benin). According to opinion of a specialist officer, from Regional Centre of Agricultural

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Promotion (CerPA), the shown groundnut seeds in Fig. 1 belong to an hybrid variety ensuing from Valencia and Spanish, two of the known four (04) groundnut varieties named as Virginia, Runner, Spanish and Valencia (Boulay *et al*, 2008; Schilling *et al*, 1996; Gillier and Silvestre, 1969; Souci *et al*, 2008).

Figure 1- Photography showing a pinch of groundnut seeds or peanuts.

Processing of Groundnut Patties

Grinding of groundnut seeds and extracting contained oil are two main steps prior that of patties production in the craft process. In reality, when using groundnut pods, manufacture of patties can be divided in steps including those of shelling groundnuts in pods, seeds sorting (separation of putrid seeds), roasting, skin removal from roasted seeds, grinding of cotyledons, pulp kneading with tidy water incorporation, hand – pressing – with oil extraction, both the last two steps were subsequently repeated until the dough almost free of oil. It followed the crushing seeds residue, oil depleted, raw-material for patties manufacture. The best crushed seed residues, suitable for manufacturing patties, were those containing at least 26% by weight of oil (Cornelius and Colld, 1975). For those relevant fried biscuits or patties locally called kluiklui, the following further transformation steps were required: dough seasoning using selective ingredients (salt, spices, hot pepper, garlic or onions), mixing, cutting of seasoned dough into pellets of equal masses of about 10 g, rolling the pellets into cylindrical sticks of about 8-10 mm or into other chosen commercial forms (Fig. 2), deep-frying those rolled sticks at oil temperature range of 140–150°C during 6–8 min, squeezing-cooling the fried patties at surrounded conditions (about 40°C) and finally wrapping them. The low profitability of patties business led producers to sometimes incorporate into the groundnut defatted dough, some quantity of maize flour. Subsequently, it result a larger quantity of variant patties of course, but their quality seemed dubious. We've then chosen to scrutinize the effects of the added maize flour at respective percentages of 5%, 10%, 15% and 20% (mass basis) on some quality indicators of these feigned patties. Let's emphasize here that, all our attempts, to carry out tests on more high maize flour percentage than 20% into groundnut dough, case of 25%, were fruitless. For effective realization of these viewed analyses, tests were focused on manufacturing of optional patties based on the mixtures of defatted dough from groundnut seeds and crude maize flour. The adopted formulations for the produced patties were disclosed in Table 1 showing explored percentages of both the used two raw materials in mix.

Table 1. Percentages constitution of used mix in manufacturing of studied patties: groundnut defatted dough (cake) and added maize flour

Masses (g) or percentages (%)	
Groundnut seeds cake	Added maize flour
100	0
95	5
90	10
85	15
80	20

Performed Measurements on Obtained Patties

In human food, quality was defined as the suitability of food in company of its consumption, itself based on three fundamental values: safety, feeding and appetite. The mechanical properties, mainly those related to reactions of a food material to shear - stress, were the most studied and widely applied for quantifying the food texture. They included the hardness, elasticity, adhesion and viscosity (Roudaut *et al.*, 2002; Valles - Pamies *et al.*, 2000; Bourne, 1982). Knowledge of texture of a built food was essential for quality appraisal by a consumer because it determined its acceptance or refusal. However, it's roughly impossible fully describing the food texture by instruments. Measurement of intensity of the feeling was made coherent by the use of specific scales slightly objectives, because sensation varied from one person to another (Dacremont, 2003; Fillion and Kilcast, 2002). Sensorial evaluation, done by a well-trained panel, was required (Sauvageot and Depledt, 2002; Moskowitz, 1996; Barrett *et al*., 1994; Seymour and Hamann, 1988). Objective and precise measurements of food hardness must be achieved with the aid of texture analyzer (Friedman *et al.*, 1963) that simulated the chewing actions of human mouth as well as a penetrometer. Nevertheless, all of the sensorial parameters of food couldn't be detected by texture analyzer (Duizer, 2001; Winquist *et al.*, 1999). It's moreover indispensable that the patties being methodically conditioned before evaluating the mechanical parameters. Reliable measurements on crunchy foods depend on their moisture contents (Roudaut *et al.*, 2002; Sauvageot and Depledt, 2002). For all those cited reasons, characteristics as moisture content, apparent density, volumetric expansion ratio, crunchiest quality and break strength of the produced variant patties were determined in current work.

Patties Moisture Content Determination

The content moisture measurement was carried out according to the standard AFNOR NF EN ISO 2010 712V03-707. Using a rotary mill Retch, the rolled in sticks groundnut patties, were cut into pieces and reduced to fine particles. Six (06) samples of initial mass M_i=10g were taken from each patty variant with the aid of a precision laboratory Mettler type, Sartorius BP3100S (3100g, resolution 0.01g) and pre-weighed empty aluminum cups. These samples were oven dried in a ventilated Memmert L400-D6060 at 105±2°C for 24 hours (at least 8 hours). They were periodically weighed at 1hour intervals until reaching constant mass (M_f), as it must be recorded from three consecutive weighing. When exiting samples out of oven, and before each weighing, they were cooled in NALGENE ISO 9001 desiccator for about 10 min. The sample moisture content value (W_E in dry basis) was deducted according to the classical relationship:

$$W_E = 100 \cdot \left(M_i - M_f\right) / M_f \quad (\%) \quad \text{(dry basis)} \qquad (1)$$

The retained value for moisture content of each patty variant is arithmetic mean of those obtained from the six (06) samples.

Density Determination on Patties

Preliminary performed tests on the rolled into sticks patties and cut in pieces of H=30mm length (Figure 2), have shown that the measured pieces of sticks were not perfectly cylindrical. So, apparent density (ρ_a), defined as ratio of mass (M_a) of groundnut patty sample freely weighing in laboratory to the corresponding apparent volume (V_a), was adopted in that case:

$$\rho_a = M_a / V_a = 4 \cdot M_a / \left(\pi \cdot H \cdot D_a^2\right) \quad (\text{kg.m}^{-3}) \qquad (2)$$

where V_a is calculated volume using classical formula $V_a=(\pi.H.D_a^2)/4$.

The retained diameter value (D_a) was arithmetical mean from three measurements taken at three levels of each 30mm cut sample as it's

shown on Fig. 3. For that, a ZKY-150 mm (0.01mm) stainless digital caliper was used, measurements taken respectively at 5mm from the first end (D_1), in the middle of sample (D_2) and at 5mm of the second end 2 (D_3). So, D_a was deduced using the formula: $D_a = (D_1+D_2+D_3) / 3$. Afterward, those same measurements were repeated on twelve (12) of the 30 mm cut samples for each variant of the produced patties, in view of improving reliability and repeatability of the determined values for D_a and subsequently V_a. Such a procedure has been developed for density determination in the expansion characterization for some cooked-extruded products (Alvarez-Martinez *et al*, 1988).

Figure 2. Photography showing variant commercialized groundnut patties in Benin: on the top of picture, is shown the chosen rolled in sticks form in this study.

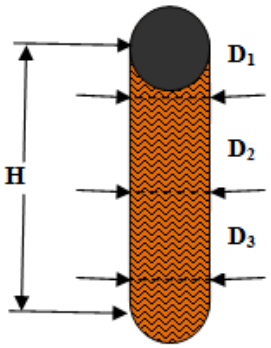

Figure 3. Sample model of the rolled in sticks variant patties cut into slabs of height H=30mm showing the three levels of acquired diameters (D_1, D_2, D_3)

Used Method for Assessing the Patties Expansion Ratio

The volumetric expansion ratio (ε_v) was defined as the calculated percentage ratio, between the induced volumetric change (V_c-V_o) by frying - cooking on a patty sample of initial volume (V_o) and the recorded final volume V_c (cm^3). Cubic shape samples 1x1x1cm^3 of defatted dough were adopted in these experimental tests series just before the frying stage. Then, expansion ratio (ε_v) has been expressed by the followed equation:

$$\varepsilon_V = 100 \cdot (V_C - V_0)/V_0 \qquad (\%) \qquad (3)$$

where (V_o=1 cm^3) was the dough sample volume before frying and (V_c) the resulting patty volume (cm^3). The choice of cubic shape samples simply linked with the fact that the defatted dough was easier to mold and measure in this shape kind using a caliper than that on the cylindrical samples corresponding to those of the rolled in sticks patties. However, values of both these two volumes (V_o) and (V_c) could also be drawn from the previous measured diameters according to the described procedure devoted to apparent volume of the exploited different patties formulations / variants.

Estimation of Crunchy Quality of the Patties

The produced five (05) patties variants according mixtures of Table 1 were subjected to tests for crunchy tasting. This was sought for assessing the level of understanding the concept of crispness by citizens, nor trained in laboratory, nor chosen for any sensory acuity. They were simply accustomed on consuming groundnut patties. In these kinds of tests, interviews generally concerned 100 to 400 persons and results used for prediction of attitudes of target populations. In current tests, the adopted panel sample consisted of one hundred (100) students of General Educational College 1 of COVE (Benin), a well known locality for its higher production and consumption of kluiklui. The inquest papers assigned letters A, B, C, D and E for masking patties variants made respectively of 0% (pure defatted cake) and 5%, 10%, 15%, 20% added maize flour. The instructions given to respondents was: "Note, without consulting your neighbors, the crispness of the five (5) patties variants A, B, C, D and E, using the rating scale coded from Very Good (VGO), Good (GOD), Fairly Good (FGO), Passably Good (PAG), or Poor Quality (POQ) to Bad Quality (BAQ).

Patties Resistance to Break Strength Measurement

The break strength maximal value was the chosen parameter for mechanical characterization of the patties. In this measurement procedure, sticks of the five (05) variant patties were cut into pieces of 30 mm-long samples. As we've deduced it from preliminary experimental results, the patties remnant moisture contents, according to mass percentages of added maize flour, were different. For this reason, the cut patties samples were subjected to oven-drying at 45±1°C, at relative humidity of 35±3% for 24 h, for moisture content homogenization. These samples were then tested in radial compression using a suitable mechanical 500 N (max) Lab and Co press type. This choice of radial direction was not fortuitous. It provided a best simulation of customary setting of the rolled in sticks groundnut patties between teeth during their mouth chewing.

RESULTS AND DISCUSSION

The valuing of defatted dough from groundnuts crushed seeds in human food, through patties production, could only become a truly carrier business if all of the manufacture steps and conservation packaging were well secured in sense of the products safety. A major factor, at this level of actions, was the mastery of patties residual moisture content for cancelling the connected risks to a higher water activity in products than normal.

Results of Patties Moisture Contents

Measurements of moisture content of tested patties yielded these shown results on Fig. 4. Those recorded data allowed us retaining that, more the percentage of crude maize flour in the defatted seed dough increased, higher was the patties remaining moisture. Indeed, to percentage values of 5%, 10%, 15% and 20% of added maize flour to groundnut defatted dough, respectively have corresponded average moisture contents of 9.61(±0.11)%, 10.82(±0.06)%, 11.61(±0.37) and 13.55%(±0.24)% (dry basis) against 8.74(±0.24)% for patties samples without maize flour (0%). The shown behavior of patties moisture content (Y), according to the added maize flour percentage (X) to groundnut seeds cake, could be modeled using the trend equation:

$$Y(X) = 0.122 \cdot X^2 + 0.42 \cdot X + 8.74 \qquad (4)$$

the correlation coefficient R^2 value being equal to $R^2 = 0.99$.

Such obtained results suggested that, some constituents of the added corn flour have generated some water retention in the produced patties structure during frying - cooking phase in comparison with pure seeds cake. In reality, by depositing those rolled sticks obtained from dough pellets in the hot oil, they were committed to be

moderately heating up. This ensured heat usually generates vaporization of the contained water and subsequently provoking dehydration of the fried-cooked patties. Additional analysis was then needed for better understanding the effective actions of the added maize starch in this observed enhancement in residual moisture content of those produced patties. Nevertheless, we must underline that, when those different patties variants were exposed to open air in laboratory at 25±1 °C, 76±3% for about 96 h, highest percentage added maize flour patties variant (20%) had been softening more quickly than the others.

This was followed in order by those containing respectively 15%, 10% and 5% maize flour (mass basis). It took longer exposure time, up to 144h, for observing the same degree of softening for groundnut patties resulting from the pure seeds cake (0%). In addition, one could also observe that moisture content values of all the patties' variants were relatively higher than those adopted in the Groundnuts Export Standard Codex 200-1995: 8% for nude seeds and 10% for seeds in pods. In view of estimating the true sustainability for patties conservation status, we could notice that, virtually no data exist on the moisture content value. However, the effects of water activity of many food products compelled us predicting water content values of less than 6% for a better sustainable conservation of studied groundnut patties. The obtained patties moisture values, from 8.74 to 13.55%, were thus higher and consequently hindered a need of extending the drying stage of produced patties as suitable frying outcome. As we knew it, the latter was itself another kind of drying process. For effectively realizing this extension drying step, hot air technique was chosen. The fried patties were then treated in moderately soft operating conditions in a D6060-L400 MEMMERT oven drier setting to temperature of 45°C, at air velocity of 2.2 ms^{-1}, relative humidity of 35±3%, for at least 8 hours. The selected conditions were those already successful proved in the drying of other foods (yams and cassava chips, pineapple, beans) before package-sealing for sustainable preservation. The same running conditions have allowed us to experimentally reducing the patties moisture content and achieving the attained good results.

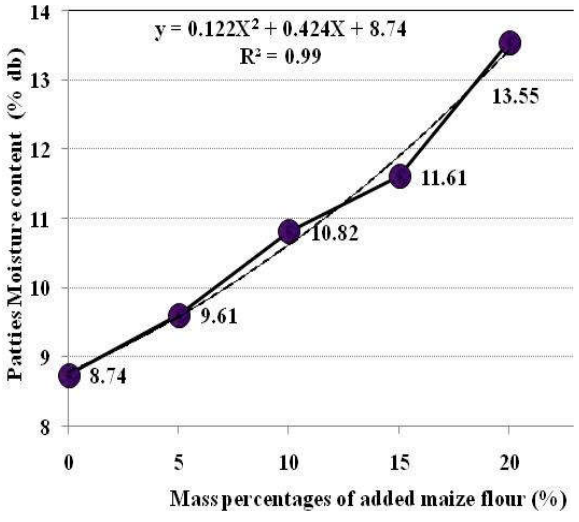

Figure 4. Behavior of patties moisture content versus mass percentages of added maize flour to the defatted dough of groundnut seeds

Results of Patties Density Measurements

The exploitation of measured diameters (D_a) allowed estimating the value of bulk density for each of the twelve (12) samples per variant of patties. Mean values were shown on Fig. 5. One observed that patties made of pure defatted dough exhibited an average density of 0.921±0.031g/cm^3. It has turned out to be the heaviest, because alternatives with 5%, 10%, 15% and 20% added corn flour displayed respective values of 0.910±0.020g/cm^3, 0.903±0.023g/cm^3, 0.900±0.027g/cm^3 and 0.898±0.015 g/cm^3. These experimental results showed that, as far as the mass percentage of added corn flour increased in the seed cakes, the densities of peanut patties decreased. The most plausible explanation of fact might mainly be based on volumetric puffiness of the patties samples to the detriment of their respective masses. Indeed, the used groundnut dough dumplings of nearly identical (10±0.13 g) masses were rolled in sticks. The mathematical model that well describing the behavior of patties density (Y) made from groundnut cake supplemented with corn flour (X) has a polynomial trend expressed as:

$$Y(X) = 0.00012 \cdot X^2 - 0.0028 \cdot X + 0.9210 \quad (5)$$

with a correlation coefficient equal to $R^2 = 0.9996$.

Moreover, the recorded results were interesting because the bulk density could be regarded as an indicator parameter for differentiating offered formulations of groundnut patties to consumers. It could contribute as a quality control parameter for raw materials entering patties manufacture, case of one was interested into discovery of which one derived from pure crushed seeds defatted dough of groundnut.

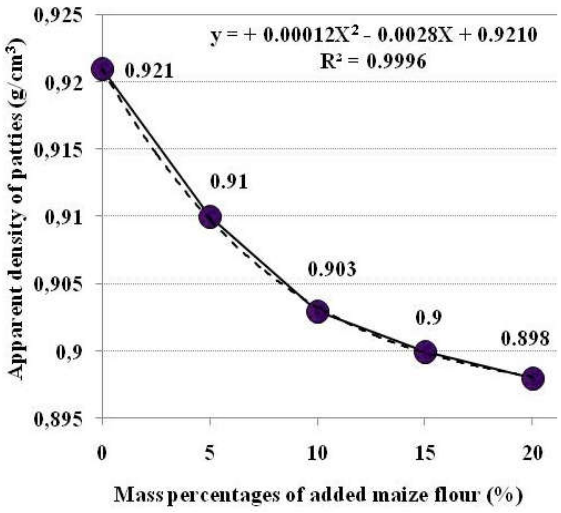

Figure 5. Behavior of patties apparent density versus mass percentages of added maize flour to the defatted dough of groundnut seeds

Results of Patties Expansion Ratio

Exploitation of the recorded data from measurements of expansion rate of the rolled in sticks patties, before and after frying, led to results shown on Fig. 6. The exhibited values were averages of those obtained on twelve (12) samples per variant of the produced patties. They clearly showed that the peanuts pulp dough had expanded during the frying. Moreover, as the percentage of added corn flour to pure seeds cake increased, average ratio of volumetric expansion (ε_v) enhanced. In fact, from 11.29±4.43% for defatted dough without any corn flour (0%), the volumetric expansion ratio rose respectively to 12.42±8.40% when adding 5% maize flour (mass basis), 17.68±7.10% at 10% maize flour, 19.13±5.94% for 15% corn flour and 20.04±6.88% at 20% corn flour. It could be seen that these obtained results well supporting those reached in previous section relating to puff up of patties volume at constant mass. The mathematical model, which adequately describing behavior of volumetric expansion of patties samples (Y), resulting from addition of mass fraction (X) of maize flour to the groundnut crushed seeds during manufacture, was found to be polynomial (Fig. 6). It could be expressed by the following trend equation:

$$Y(X) = -0 \cdot 003 \cdot X^3 + 0.081 \cdot X^2 + 0.058 \cdot X + 11.13 \quad (6)$$

with a regression coefficient value of $R^2 = 0.971$.

The volumetric expansion ratio (ε_v), like the bulk density, could also be used as a descriptor parameter for differentiating the patties formulations in Benin. As it's shown, a comparative higher value was

obtained for patty made of mix groundnut and maize four than that from the pure seeds cake. As we done it, a quick control test could then be based on a fast ε_v-ratio detection by choosing standard dough sampling, dough samples of well known cubic dimensions for example (V_o), from the different patties formulations and submitting them to frying. After that, measurements of cooked patties new dimensions took place (V_c) for quick calculation of ε_v-ratio in percentage.

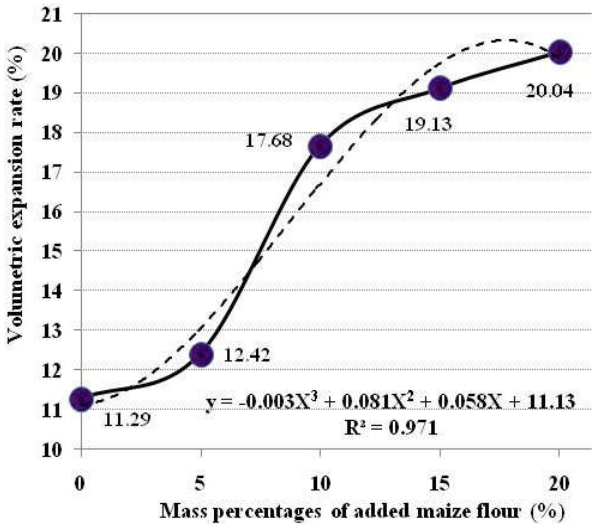

Figure 6. Behavior of patties volumetric expansion ratio versus mass percentages of added maize flour to the defatted dough of groundnut seeds

Results for Crunchy Tasting of Produced Variant Patties

The obtained results, in displaying the inquest papers, were those shown in Table 2. On basis of the recorded data from this survey, the two patties variant A and B, respectively from flourless defatted groundnut dough (0%) and 5% (mass basis) added maize flour, were both clearly different from the three others (C, D and E) as they're the two crunchiest patties formulations.

patties containing 20% maize flour was highly crunchiest than those respectively made of 15%, 10% and 5% maize flour, the pure defatted dough of groundnut seeds laying at the last.

Patties Break Strength in Radial Compression

The data from break strength measurements of the five (05) patties variants furnished the exposed results in Fig. 7. Analysis of those recorded values clearly showed that, when the percentage of added maize flour to defatted seed cake was increased, the required break strength for patties decreased. Thus, reducing patties resistance against the exerted compression strength obviously facilitated their chewing. In reality, the obtained break strength (Y) average values, on twelve (12) samples basis per variant patty, varied from 215.54±7.42 N at 0% mass flour to 166.28±11.30 N (20%). The mathematical model, which adequately describing behavior of patties resistance, resulting from the mass fraction (X) of maize flour in peanut seeds defatted dough, during manufacture, could be expressed by trend equation:

$$Y(X) = 2.612 \cdot X^2 - 28.08 \cdot X + 215.54 \quad (7)$$

where regression coefficient value being of $R^2 = 0.999$.

Those results let predicting that, the greater the break strength supported by a variant of patty, more difficult be its chewing in mouth (on teeth) and less crunchy it was. This exhibited behavior of patties texture in compression tests had suggested that the introduced maize flour had property for weakening some bonds that provided rigidity to structure of the derived patties from pure defatted dough. It's then convenient to think that some reactions have effectively occurred. Those could first be attributed to the contained total starch from both the maize flour and defatted groundnut meal mix that forming the cut dough into pellets and rolled into sticks. The starch, major of carbohydrate components of maize grain endosperm that account for 69-73% dry matter basis (Eggum *et al*, 1979; Aguilera and Lusas, 1985), was suspected to be gelatinized proportionally to existing quantity in resultant dough. Thus, the greater the percentage of added maize flour, the larger the amount of starch in dough, rising at best the degree of gelatinization which took place in presence of the combined actions of inner moisture and generated heat from frying-oil at about 120°C.

Table 2. Results of the realized sensorial test for appreciation of crunchiness quality of the five (05) variants of groundnut patties (kluiklui) using 100 - persons panel basis

Codes of variant tested patties and added maize flour percentage		Encoded notations for adopted scale and the recorded data						
		VGO	GOD	FGO	PAG	POQ	BAQ	Total panel
Codes	*Flour (%)*	Very Good	Just Good	Fairly Good	Passably Good	Poor Quality	Bad Quality	
A	*0*	2	5	3	7	22	61	100
B	*5*	5	6	5	9	27	48	100
C	*10*	23	19	31	16	8	3	100
D	*15*	61	26	7	2	3	1	100
E	*20*	72	21	4	0	0	3	100

After those, the patty variant C came to confirm this observed tendency. Since, from the three other tested mixtures, patty C result as the lower flour containing defatted dough. Moreover, it could be retained that, when 5% (mass basis) flour was added to the defatted groundnut dough, patties quality was very little different from the one no maize flour containing (0%). These results also permit concluding to the success of the realized sensorial test in discerning crispy (crunchy) of patties from groundnut flavor they have certainly previously memorized. Despite our initial difficulty connected with the use of untrained panel, the respondents overcame by successfully well esteeming the crunchy quality of tasted patties. Indeed, crunchy characteristic was intimately linked with structural expansion of material in food products (Bourne, 2002; Alvarez-Martinez, 1988). The crispness derived in fact from micro cavities and micro cracks generation within a product, facilitating its rupture (Barrett *et al*, 1994; Alvarez-Martinez *et al*, 1988). We came to conclusion that the

Moreover, those coupled effects of heat and moisture in fried matter had generated vaporization of patty inner water. This took place apparently at corresponding pressure to prevailing condition in hot oil (about 120°C), pressure necessarily greater than that immediately out of oil. At the end of frying, the roasted patties were set to relative cool conditions: about 40°C and at atmospheric pressure. It presumably followed some relaxation – cooling mechanisms that subsequently generating micro cavities in the fried patties' structure. The micro cavities or micro air pockets constitute foundation for the recorded expansion as supporting by results from expansion ratio measurements in subsection 3.3. The patties then displayed crunchiness to level of those generated cells. It's known that size and starch gelatinization promoted better development of micro air pockets in products structure (Dacremont, 2003; Brown and Braxton, 2000; Seymour and Hamman, 1988). Patties, resulting from defatted dough of groundnut seeds supplemented with crude maize flour,

belonged to this category of products. Undeniably, the more maize flour percentage in groundnut dough grew, obviously its starch content, the more micro cavities and micro cracks were developed in fried patties structure and crunchiest the derived patties.

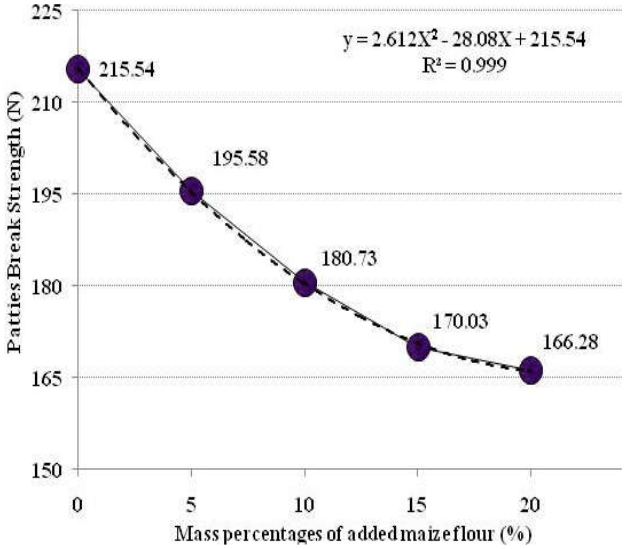

Figure 7. Behavior of patties resistance to break strength versus mass percentages of added maize flour to the defatted dough of groundnut seeds

Conclusion

The reported research in this paper was devoted to a better knowledge of groundnut patties properties according addition of crude maize flour. We've analyzed some physical and mechanical characteristics that could serve as descriptors parameters for crunchiness of produced variant patties rolled in sticks in Benin. For that, moisture content, bulk density, volumetric expansion ratio, break strength, were studied concurrently with the influence of mass proportions of added maize flour to defatted seeds dough. Concordant results were obtained showing globally that the moisture content of patties was high after manufacture. A long storage required that an additional drying be applied to patties at the end of frying phase. Moreover, when mass percentage of incorporated maize flour into pure defatted groundnut dough increased, the apparent density of patties on one hand, and their resistance to rupture in radial compression testing on the other, decreased while volumetric expansion rose, making thereby the resulting patties more crunchiest.

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