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RESEARCH ARTICLE

EFFECTS OF THE TORREFIED SOY FLOUR INCORPORATION (DEVOID-OF-DANDRUFFS OR NOT) ON SOME PHYSICOMECHANICAL AND SENSORY PROPERTIES OF MAIZE PATTIES ROLLED-INTO-STICKS

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ABSTRACT

Maize plays a very important role in the daily diet of the Beninese populations with a high level of consumption varying according to the different zones of the country. Among the Beninese food products, maize is the subject of the greatest number of food transformations with about forty derived products, including crispy patties "*klèklè* (resp. *kluiklui*)" obtained from flours of dry ordinary (resp. roasted) grains. Rich in carbohydrates, maize kernels are unfortunately poor in protein, lipids, minerals, fibers and vitamins. Combining maize with soya, a natural legume rich in essential proteins and nutrients, the noted deficit can be filled and simultaneously resulting patties quality improved. Therefore, what will remain of the so prized patties crispiness by consumers? This article aims at studying the effects of soy addition, provided in two flours types (entire grains and freed-of-pellicles), both torrefied, to maize flour, during patties' manufacture, on some quality characteristics: physical (residual moisture, density), mechanical (expansion rate, breaking strength) and organoleptic (taste, color, crispiness). The achieved results are interesting and reveal that residual moisture of the confectioned patties, using the shelled soy-grains, decreased (7.22±0.79 to 5.62±0.37%) with augmentation of soy-flour content (0-20%). Addition of the unshelled soy-grains first drastically dropped patties' residual moisture (7.22±0.79 to 3.46±0.63%), and after, induced its increase (3.46±0.63 to 6.38±0.41%). However, these values of maize-soy residual water contents remained lower than that of the control patties (7.22±0.79%). Opposite trends were obtained for densities with regards respectively to the two torrefied soy-grains flour kinds where densities of maize patties made from shelled soy-grains increased (0.71±0.04 - 0.83±0.08 g/cm^3), unlike those provided from non-decorticated (0.71±0.04 - 0.67±0.08 g/cm^3). The volumetric expansion rates have all displayed increase trend, regardless the formulated patties were from the shelled soy-grains (4.83 - 25.5%) or not (0.91 - 11.75%), calculated ratio related to the control patties. Although they disclosed relatively higher expansion rate values, the maize patties made of shelled soy-grains have got the best crispness scores (40.00 - 44.44%), just after the control variant (31.00 - 40.00%). For the general appreciation, consumers' preference was rather oriented towards the elaborated maize patties from shelled soy-grains (42.22 - 44.44%).

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INTRODUCTION

Cereals, in diversities, are now basis for many products constituting the human and animal food (Burgess, 2005; Brink et Belay, 2006; Branger *et al*., 2009; Demarquoy, 2014). Indeed, the food industry evokes an important part from daily cares of man and determines his intellectual development. A healthy and balanced diet, both in quality and quantity, is required (Leray, 2013; Chanussot, 2008; Burgess, 2005). Agriculture and food industry are not yet able to meet the needs increase, ever more varied and exigent urban consumers: quality, origin, practicality, diversity of tastes,etc. Agricultural processing sector in Benin faces today many challenges ahead (technical, organizational, commercial) and constraints linked to environmental services essential to its growth (Insae, 2013; Anonyme, 2012; Sanya *et al*., 2009).In recent years however, many African craftsmen are committed to promote local transformation of agricultural crops tomake available various products edible or not, like fruit juices, variant patties (peanuts, bananas, corn, soy, cassava, taro, yams), shea butter, locust beans, *Pentadesma,* etc.(Iwuoha, 2004; Oluwolé *et al*., 2007; Yé *et al*., 2007; Sanya *et al*., 2009; Ahouansou *et al*., 2012). In West Africa and especially in Benin, artisanal made maize patties, called "gbadé-klèklè" in *fon*or "klaklu" in *goun* dialects, like peanut seeds manufactured ones (Guédou, 2010; Paulet, 2010; Sanya *et al*., 2013; 2015), constitutea type of snack food quite appreciated by people. This strong affection reserved for patties certainly finds reason in crunchiness/ crustiness of these products. Maize, *Zea mays L., 1753*,(Carrareto, 2005), is fairly rooted in Benin's food(Adjadi *et al*., 2015). It's remained the most produced cereal in Benin with 1,572,671 tons and nearly 98% of households consume daily a maize-based food in southern Benin (Insae, 2013). Its field is undeniably important because occupying 47.4% women processors and sellers of food products in Cotonou city alone. Among Beninese food crops, maize makes subject of largest number of transformations: over forty derivatives including donuts "*klèklè*" and patties "*klaklu*" obtained respectively from ordinary dried grains maize flours and torrefied ones (Fao, 2010; Adjadi *et al*., 2015).

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Whatever the selected formulation and the applied process, consumption of maize (1.4 to 9.4% by weight of proteins and 0.3-3.8% fats) is often accompanied by a qualityenricher, a very ancient practice justified by his poverty in essential nutrients (Burgess, 2005; De Reynal, 2009; Bergezet Abecassis, 2009; Demarquoy, 2014; Schneider et Huyghe, 2015; CIC, 2016). To compensate for this deficit, we associate animal/fish proteins, vegetable proteins especially legumes including soybean (Glycine max L. Merr., 1917), lipids and vitamins(Latham, 2001; Roberfroid *et al*., 2008; De Reynal, 2009; Mérie, 2011; Leray, 2013).

Neighbour of bean and native of Asia (Northern China), soy is a legume now widely cultivated in the world, especially in America, for its oilseeds (Usda-Ars, 2000, 2015; Fao Stat, 2015). It's the richest of the world plants in proteins, constituting in major part of globulins completely insoluble at their respective isoelectric points (4.5 to 5.9), but soluble in presence of salts (Usda-Ars, 2000; Bauer *et al*., 2010; FaoStat, 2015). Soy-grain has excellent intrinsic nutritional value: proteins (36.54 to 46% by weight, a digestibility of 98%), fats (12 to 24.0%), carbohydrates (about 30%), amino-acids (essential and not), other nutrients, as minerals (phosphorus, potassium, calcium, magnesium, zinc and iron) and various vitamins include A, B, C, E (Usda-Ars, 2000; Burgess, 2005; Chanussot, 2008; Guéguen et Duc, 2008; Bauer *et al*., 2010; Bhagwat and Haytowitz, 2015).

Soy-flour incorporation into maize-patties' formulation is an innovative form of enrichment of functional quality in comparison with the traditional single maize made patties, salty and/or sweet, using a flavour ingredient as anise (*Pimpinellaanisum, 1753*) (Guédou, 2010; Sanya *et al*., 2015). Such established coupling, soybean-maize, turns into interesting complementarity, because soy addition to human daily diet can bring satisfying answers to its nutritional needs (Burgess, 2005; Roberfroid *et al*., 2008; De Reynal, 2009; Demarquoy, 2014). Also, do we sometimes eat patties, just for crustiness enjoyment and simple pleasure they provide, especially when properly stored away from moisture (Sanya *et al*., 2015, 2016)! It's why this article aims to explore the induced effects by incorporation of obtained flours from the torrefied soy-grains (skinned, and not skinned), on some physico-mechanical and sensory characteristics of soy blended maize patties in reference toclassicallypure maize made ones.

MATERIALS AND METHODS

Materials

Maize grains

The maize seeds used in this research work belong to the variety all comers as can be seen on the extracted sample of Figure 1-1 showing a mix of yellow and white grains maize species.

They were purchased from professional sellers, at Dantokpa international market of Cotonou, usual source of raw materials of manufacture maize patties, for women producers operating in the vicinity of the economic capital of Benin (Sanya *et al*., 2016).

Soy-grains

The soy-grains used in present work are a mixture, thus belonging to all comers variety (Figure 1-2), also acquired from sellers at Dantokpa, international market of Cotonou (Benin).

Needed ingredients: green anise, salt and/or sugar, water

Green anise, salt, and sugar were various ingredients commonlyused to prepare the patties and havealso been acquired atDantokpa marketand water was that from the public network.

Patties' manufacturing equipment

The material used for formulation and manufacture of the tested nine (09) maize patties variants includes:

- A laboratory balance, of brand Sartorius, capacity 3100 g and 0.01 g accuracy, for weighing different raw materials as maize and roasted soy flours, sugar, salt and anise;
- AnOryx-gas furnace and accessories, to light the fire and ensure the required heat for the realized tests;
- Various kitchen utensils (pots, palette, perforated spoon, cups, graduated cylinders, bowls, and sieves, .. etc.), for different operations
- Various useful others, for transport, product packaging and storage (trays, plastic bags, aluminium foil of in thin sheets, about 0.02 mm thickness), samples' identifiers such as adhesive tape and markers. For conservation of the various flours and powders (maize, soy-grains, sugar, green anise, grounded patties) and cut patties' samples, transparent plastic-bags and aluminium foil were respectively used.

Shapes and sizes of maize patties

Patties' dimensions vary, depending on the unit selling price, but are typically between 150 and 250 mm in length, 5 to 12.5 mm diameter (Guédou, 2011; Sanya *et al*., 2015). The adopted shape is cylindrical – truncate conical one of 200 mm length and 8-10 mm diameter.

Patties characterization material

For the characterization of witnesses patties and those roasted soy grains flour incorporated (skinned or not skinned), different instruments and devices were used for sampling patties and measurements. It can be noticed the:

- FACOM digital calliper: it was used in measuring dimensions (diameter, height) of rolled-in-sticks pulp samples before frying and resultant patties after cooking-frying;
- aluminium cups: they serve as supports for samples in the hot-air oven-drying tests;
- cylindrical jug, 30 mm height and 6 mm radius, made for pre-sizing the patties samples in order to avoid material losses by breaks during their cutting;
- laboratory weighing scale: of type Sartorius, weighing capacity 3100 g and 0.01 g accuracy, it's used in weighing maize flour, roasted soy grains flour, sugar, salt, and anise in a hand, flavoured pulp samples rolled into sticks and patties, according to requirement of each variant of patties, and to monitor the masses when determining the water content, on the other.
- laboratory ventilated oven-dryer: it's of MEMMERT brand, D06060 type and L400 model, ranging temperature of 30 to 225 °C. It served for hot-air drying the crushed patties, during water content determination and in the homogenization pre-treatment assured to various samples, just before their breaking strength evaluation;
- standard Multifunction Environment Meter 4-IN-1 device: ST-8820 model, combining hygrometer, thermometer, sound level meter and photometer functions, this unit served through its K-type thermocouple in the checking of oil temperature evolution during frying-cooking of the formulated different variants of maize patties;
- TA-XT texture analyser, provided by Lloyd Instruments (a division of AMETEK Company) and developed to test physical and mechanical integrity of all food products, particularly in resistance rangingof 0 to 500 N, was used in strength testing.

Methods

After description of the vegetable materials and technical equipment, are presented the adopted methods in the formulation, manufacture of the studied variant patties and assessment of the retained physical and sensory characteristics.

Formulation of soy blended maize patties

The maize patties "*klaklu*" mean a product obtained from a cooked porridge, salty and / or sugary, consolidated by the raw dry flour, and

Figure 1. 1.1-Localmaize grains, 1.2-Soy grains, 1.3-Green anise, 1.4-White cane sugar, 1.5-Rolled-in-sticks' paste, ready-to-be fried

Table 1. Adopted formulation in manufacturing the studied nine (9) patties' variants

Variantmaize-soy patties ($V_{PH/U}$)	Maize flour percent (%)	Mass of maize flour (g)	Soy grains flour percent (%)	Mass of soy grains flour (g)	Added sugar percent (%)	Addedkitch ensalt percent (%)	Added green anise percent (%)	*Observations on the applied treatments*
$V_{MP0\%}$	100	78.02	0	0	20	1.8	0.18	*Witness patties*
$V_{PH5\%}$	95	74.12	5	3.90	20	1.8	0.18	*Shelled (freed-of-*
$V_{PH10\%}$	90	70.22	10	7.80	20	1.8	0.18	*dandruffs) and*
$V_{PH15\%}$	85	66.32	15	11.70	20	1.8	0.18	*Torrefiedsoy grains(h)*
$V_{PH20\%}$	80	62.42	20	15.60	20	1.8	0.18	
$V_{PU5\%}$	95	74.12	5	3.90	20	1.8	0.18	*Unshelled (whole) and*
$V_{PU10\%}$	90	70.22	10	7.80	20	1.8	0.18	*torrefied soy grains (u)*
$V_{PU15\%}$	85	66.32	15	11.70	20	1.8	0.18	
$V_{PU20\%}$	80	62.42	20	15.60	20	1.8	0.18	

then fried in a vegetable oil. The technique for producing patties "*klaklu*" requires, for 1 kg (1,000 g) of dry maize flour: 200 g of cane sugar (20%), 18-19 g of kitchen salt (1.8 -1 9%) and 1.8 to 2.0 g of green anise i.e. 0.18 to 0.2%(Sanya *et al*., 2016).Regarding of maize patties variants tested in current work, the different adopted formulations essentially based on the fact that soybean's incorporation has for only role, to offsetting deficits in vital nutrients of maize: therefore, soybean meal's mass simply replaces, identically, that of maize. Accordingly, one leaves unchanged the masses of added ingredients= 21.98% i.e. sugar(= 20%) + salt(= 1.8%) + anise(= 0.18%), in calculation of the incorporated percentages, in connection with the maize-flour mass(= 78.02 g/100 g), as disclosed in Table 1. We can then express the added soy-flour percentage, in function of maize-flour weight. The process, for production of maize-soy patties rolled into-sticks, follows the various steps described schematically in the flowchart of Figure 2.

Confection of the seasoned dough

The step of dough's preparation for maize patties (sweetened/flavoured) comprises a complex sequence of operations going from the first fraction of maize flour in admixture with the corresponding proportion of soybean, in accordance with the formulation's composition set forth in Table 1. There are, in fact, to respect the following procedure' steps:

- Put water in a properly washed cooking pot;
- Add soy-flour proportion, the part of maize-flour first fraction, anise powder and salt;
- Add sugar (if needed) and then homogenize using the paddle and let it boil;
- Add, at the end, the remainder maize-flour first portion, all by stirring with pallet, until obtaining a firm dough, sweetened and flavoured;
- Let cook this dough on fire about 5 minutes and then bring down the pan/ pot;
- Pour resultant dough into an uncovered container (preferably a tray) to let it freely cool to room temperature. Whilst dough loses heat, the water vapour is released, which traduces the heat and mass transfer mechanisms. A thin solid layer (crust) forms on the dough's surface that must be absolutely removed in order pursuing the process.

From seasoned maize dough to patties

The obtention of maize patties rolled-into-sticks, from the chilled dough, goes through the successive stages of formulation relatively described briefly below. It is:

1. Cut up into five parts, the dough after it stripped of its crust; the partition of flavoured dough into several pieces is adopted due to presence of sugar that makes more elastic kneaded dough, when it's allowed to stand long before being modelled; which usually requires the resumption of kneading;
2. Divide into five parts, the second fraction maize flour reserved early in the proceedings;
3. Add, to each piece of dough, a part of the second portion of maize flour, and mix or knead the mixture until reaching its homogenization;
4. Depositing the homogeneous mixture obtained on a table where it's cut into regular balls of about 10 g;
5. Shaping dumplings in sticks, by rolling them on the table (handmade, it's manually done, rolling back and forth);
6. Bring to fire a relatively flat pan, by pouring the cooking-frying oil, and let warm at temperature of 110-120 °c (Sanya *et al*., 2015; 2016), a cessation of cracklings marking the total departure of water contained in oil;
7. Introduce into hot-oil, each batch of the rolled-into-sticks dough, and let cook–fry;
8. Use a skimmer to submit the frying patties to turn, at about every 2 to 3 min, until they are evenly cooked;
9. Remove patties hot-oil by putting them in a strainer over a bowl, so to ensure a de-oiling, a step in which the excess oil seeps towards this bowl. The withdrawal of patties from frying oil (115±5 °c) is accompanied to some extent by theirquick cooling in the surrounding air (37±3 °c).

Patties Physicomechanical Characterization

Patties water content

The determination of water content was carried out following the provisions of the NF-EN-ISO-712 (AFNOR V03-707) with three samples instead of two. About 5 g of each ground patty variant is taken in a cup of known mass (M) and dried in a weighted cup, filled of noted sample (M_1). The whole is heated by drying in a ventilated oven at temperature of 103±2 °C, until constant mass (M_2) reached, minimum of measure duration is eight hours, typically up to 17±1 h, relative humidity on site being of less than 70%, as recommended by the steaming method at low temperature for the rich oil-seeds and approved by the International Seed Testing Association (ISTA). The constancy of mass is found by three successive weighing at regular intervals of one hour. The water content, expressed as percentage by mass on a dry basis (W), is calculated using the formula:

$$W = 100 \cdot (M_1 - M_2)/(M_2 - M)(\%) \qquad (1)$$

Where M is a mass of the empty cupel (g) ;M_1 the mass of the cupel containing the sample before drying (g) and M_2 the mass of the cupel containing the sample after the drying (g)

Assessment of patties' density

The density is often considered as one of the main characterizing parameters of the finished product in alveolated products study (Lassoued, 2005; Wagner, 2005; Zghal *et al*., 2005), like current patties, for correlation research purposes. Preliminary tests showed that the patties samples were far to be perfectly cylindrical. We consequently opted for the bulk density determination, very close to the true, for each variant of patties. So, the individual mean apparent density (ρ_i) was defined as the ratio between mass (M_i) of sample (*i*) and correspondent average volume (V_i):

$$\rho_i = M_i / V_i \quad (2)$$

where V_i: $V_i = \pi \cdot H \cdot D_i^2 / 4$ and $D_i = (D_1 + D_2 + D_3)/3$ (Sanya *et al*., 2013)

D_i : average diameter of patties' sample (i), cut into piece of H=30 mm-height;
D_1 : taken diameter at 5 mm from the first end of this cut sample(*i*);
D_2 : measured diameter just in the middle of previously cut sample (*i*);
D_3 : measured diameter at 5 mm from the second end of cut sample (*i*).

The bulk density (ρ_{VP}) of every variant of the studied patties in this work is taken equal to the average value of twelve individual samples (*i*), that's to say:

$$\rho_{VP} = \sum_{i=1}^{i=12} (M_i / V_i) \quad (3)$$

Assessment of volumetric expansion ratio

The volumetric expansion ratio, for an individual sample (E_{ri}), was here defined as the ratio between volume change of patties sample due to cooking-frying (V_{if}) and initial volume (V_{0i}) just before cooking, the two volumes measured according to previously described procedure.

$$E_{rP} = \sum_{i=1}^{i=12} E_{ri} \text{ , } E_{ri} = 100 \cdot (V_{if} - V_{i0}) / V_{i0} \text{ (\%)} \quad (4)$$

Breakingstrengthdetermination

As a prelude to mechanical test, the nine (9) variants of patties were subjected to a gentle drying at 50 °C, for at minus 12 h, for their homogenization followed by a repackaging in aluminium foils. Indeed, this homogenization treatment stayed indispensable, to bring, all the samples of these variants of patties, to the same residual water content, because moisture is well known to influence this type of mechanical testing (Valles *et al*., 2000; Rahman *et al*-Farsi, 2005; Zghal *et al*., 2005; Lassoued, 2005; Wagner, 2005;Guillard *et al*., 2013). Radial compression measurements were performed on the manufactured maize-soy patties using Texture Analyser Apparatus equipped with a WarnerBratzler probe. It's calibrated for displaying constant speed of 20 mm/min and elongation of 65 cm at hole angleof 60° developing strength values ranging from 4 to 150 N.(max), as preliminary trials showed it. The procedure of this test consists of compressing a patties sample, geometric shape adopted here cylindrical (in radial direction) by subjecting it to constant speed deformation and measuring opposed resistance to exerted breaking strength. The recorded data on stress evolution, in function of applied strain, gives quantitative informations about mechanical properties of the tested solid material.

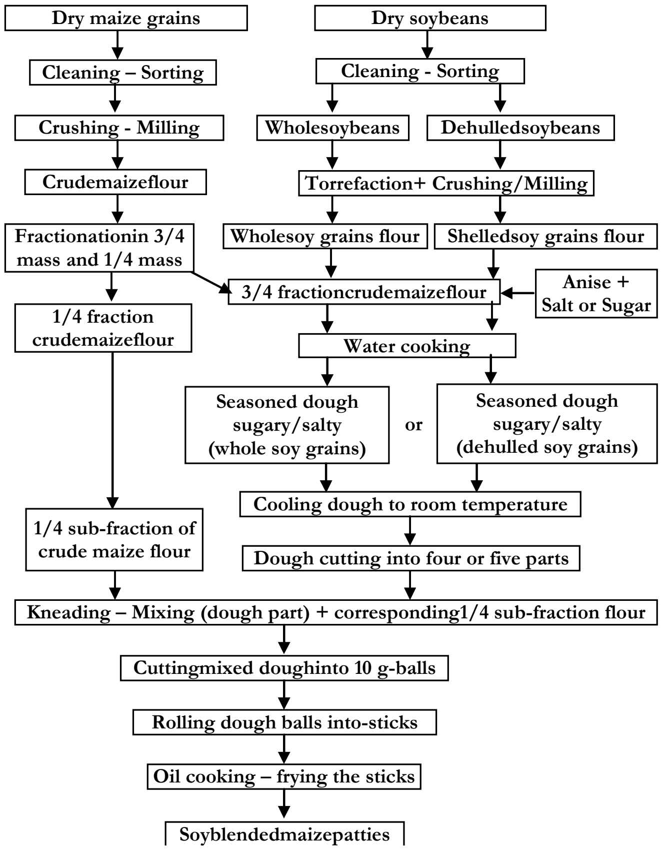

Figure 2. Flowchart of manufacturing process for soy blended maize patties

Sensory characterization

Sensory analysis methods, for assessing the qualities of a product, involve the sense organs of the human being (Fillionet Kilcast, 2002; Daniel et Roudot, 2007). Sensory analysis uses particularly precise and framed methods (Charreau *et al*., 2013). Two main approaches exist, according to study purpose: the analytical approach which comprises techniques to specifically measure the sensory characteristics of a product, and the hedonic approach which assesses the degree of pleasure derived from a product, by determining proportion of consumers preferring one product to another (Zghal *et al*., 2005; Lassoued, 2005; Wagner, 2005; Charreau *et al*., 2013).The latter, designed to measure the degree of appreciation of products, is essentially adopted in current study. Previous instrumental test by penetro meter has also been used for the purpose to seek a possible instrumental hedonic-correlation. The tasting panel is composed of 45 untrained people. These tasters' specificity was that they all have had habit of eating patties peanut and maize. The included sensory parameters, in patties characterization's analyses, are their colour intensity, their crispness (hardness, chewing number) and their overall appreciation for patties.

Pattiescolourintensity

Colour is one of the first remarkable aspects of a product. It is often linked to chemical, biochemical or microbiological phenomena, which took place inside the product during a transformation process.For evaluating colour intensity, categorization tests were adopted and consisted in carrying a notation comprised between: **1** point- abnormal colour; **2** points- normal colour (maize patties colour without soybean); **3** points- moderately caramelized; **4** points- averagely caramelized, and**5** points- strongly caramelized.

Patties degree of crunchiness

The crispiness of a product is function of its ability (including food products) emitting a dry sound when grinding during chewing. The crispness perception occurs during bite and chewing, when the product is broken on teeth. The chewing aims to reduce particles size of the product present in mouth and lubricate them for the swallowing. The crispness (crunchiness) is thus result of a complex set of elements. One finally adopts an hedonic method consisting on a good filling of the developed taste foils where tasters have simply to wear notes comprised between, (**1** point)- Not crusty patties; (**2** points)- Indifferent to patties crustiness; (**3** points)- Fairly crusty patties; (**4** points)- Just well crusty patties, and (**5** points)- Highly well crusty patties.

General sensory appreciation of tasters

This test is designed to assess the level of consumers' satisfaction for various presented patties variants. To do this, the tasters are called to appreciate each variant of patties, according to a semantic scale on a score sheet to be filled in with a note comprised between 1-Bad appreciation, 2-Poor appreciation, 3-Indifferent appreciation, 4-Good appreciation, and 5-Very good appreciation.

Statistical analysis of results

The results of the characterization tests of the nine (09) patties variants were subjected to dispersion analysis. For each variant of patties, twelve (12) samples are taken and analyzed as an individual point. The number of samples, retained for each test, corresponds to six (6) times that of individual point, that's to say, a total of seventy-two (72) samples. The dispersion indicator (standard deviationσ_i) is calculated in order to learn about how measured variables (X_i) are distributed around their different means (M_i):

$$\sigma_i = \left(\sqrt{\sum X_i^2 - M_i^2}\right) \Big/ n \qquad (5)$$

The results of taste tests were analyzed through the designed graphs from application of the Microsoft Office Excel 2010 version's software.

RESULTS AND DISCUSSION

This section presents the discussed results, related tothe studied patties physicomechanical characteristics (residual water content, bulk density, volumetric expansion ratio and breaking strength) and sensory (colour intensity, degree of crunchiness, and tasters overall appreciation).

Physicochemical Characteristics

Measured residual water content

The results from evaluation of the residual water amount in each sample of the different patties variants after frying, followed by cooling, are reported in Figure 3, along with those no-soybean made (witnesses maize patties: $\mathbf{V_{P0\%}}$). It can be noticed, first, that all the soy added patties variants (at 5%, 10%, 15% and 20% by maize flour weight) recorded lower values of residual water content (from 7.15±0.43 % to 5.62±0.37 % for the hulled grains made and 3.46±0.63 % to 6.38±0.41 % for the unshelled soy grains) than those for solely maize built patties ($\mathbf{V_{P0\%}}$) without soybean (7.22±0.79 % dry basis). Similar results were obtained earlier respectively7.32±2.47 % (d.b) and7.99±1.53 % (Sanya *et al*., 2013; 2015), averages slightly less than or equal to the allowed limit by Codex Alimentarius for efficient food packaging: 8 % (d.b). This is a serious asset for the proper conservation of so developed maize-soy patties variants. It's a very important benefit because we'll not need to perform any intermediate treatment before permanent pack these patties.

On the other hand, the residual water content of the incorporated maize patties in soy-flour obtained from hulled soy-grains decreases with augmentation of added soy-flour content, whereas it decreases for pattiesmade of unshelled soy-grains'flour. A more thorough analysis of data of Fig. 3, mainly beginning from the added soya percentages, i.e. from 5% to 20% (maize flour weight), reveals that the residual water content evolves rather according to an exponential function (Fig. 3') contrary to this indicated polynomial function on Figure 3. Indeed, the statistical exploration of the two sets data has shown that, the mathematical model which can adequately describe evolution of residual water content of the blended maize-soy patties ($W_{VPX\%}$), versus soybean flour content (X), depends on the applied treatment to soy-grains (shelled or not skinned) before roasting/Torre faction.

- For confectioned variants of patties made of flour from whole soy-grains(V_{PU}), obtained model was a power function expressed as:

$$W_{VPU} = 3.510 \cdot X^{0.438} \; ; \qquad R^2=0.98 \qquad (6\text{-}1)$$

–For confectioned variants of patties made of flour from husked or freed-of-dandruffs soy-grains(V_{PH}), obtained model was rather a second order polynomial function expressed as:

$$W_{VPH} = -0.064 \cdot X^2 - 0.008 \cdot X + 7.22 \, ; \; R^2=0.953 \qquad (6\text{-}2)$$

Comparing these two kinds of results, it's convenient to underline the importance of induced effects by the soy grains' hulls. Indeed, they seem allowing for some humidity retention inside structure of the developed maize-soy patties. Apart from the maize-soy patties variant incorporated at 20 % of soy-grains flour, the values of residual water content, of the manufactured patties using unshelled (not freed-of-dandruffs) soy-grains, are higher than those for the hulled soy-grains made patties. The obtained gaps fall between 12 and 50 %, in a calculation referring to corresponding values to case of the made maize patties of freed-of dandruffs soy-grains. One is tempted to conclude that, the more soy-flour content increases, the recorded gap in residual water content, due to the presence or absence of hulls on soy-grains, decreases, becoming simply negative in vicinity of 20% soy-flour content.

Patties density

The results for evaluation of respective densities of the nine (9) variants of patties, combining maize with soy or not, tested in this research work, are shown on the Figure4.

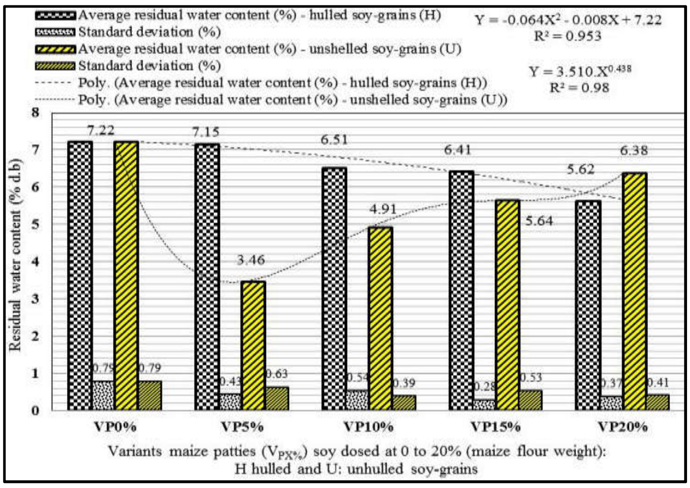

Figure 3. Residual water contents (% d.b) of maize patties' variants ($V_{PX\,\%}$) incorporated in torrefied soy-grains flour at X=0 % (control) to X=20 % (maize flour weight)

These findings indicate that the values of densities of variant patties witnesses (V_{MP0}%) and those of incorporated of soy-flour, that the latter had been obtained from unshelled soy-grains or hulled, are lower than that of water pure (1 g/cm^3). Indeed, all nine (9) variants patties float on water, when trying to immerse them. However, they're finally waterlogged, after a mean times observation of 22±3 min, according to results of the performed six (6) immersion tests, to that effect, on these variants of patties. A longer duration of final waterlogging has already been obtained for the maize patties added of sugar alone (Sanya *et al*., 2016) and also for peanut patties added of maize flour (Guédou, 2010; Sanya *et al*., 2015).

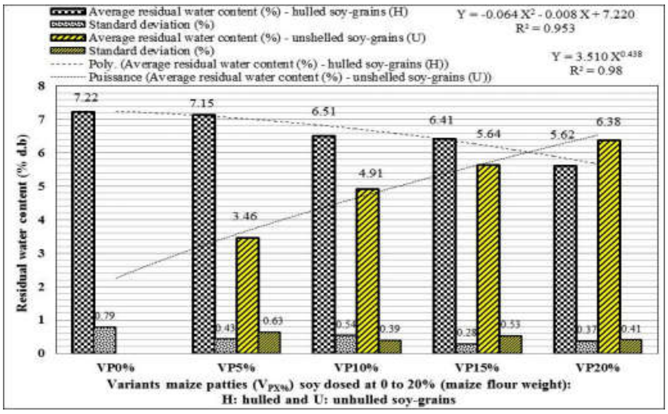

Figure 3. True trends of residual water contents (% d.b) of maize patties' variants ($V_{PX\%}$) incorporated in torrefied soy-grains flour at X=0 % (control) to X=20 %

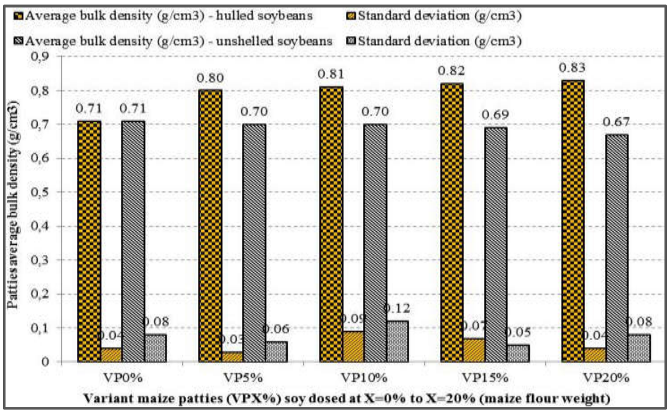

Figure 4. Bulk densities (ρ in g/cm³) of maize patties' variants (V_{PX}%) incorporated intorrefied soy-grains flour at X=0 % (witnesses) to X=20 % (maize flour weight)

The average density of patties witnesses (without soy), 0.71±0.76 (g/cm³) is less than the previously obtained value (0.812±0.08 g/cm³) but still higher than those of variants elaborated using flour from the hulled and roasted soy-grains. Note that the density thereof decreases as the decorticated soy-grains flour content increases, although the rate of decline is relatively small: between 1.5 and 6% for the explored range of soy-flour contents (5 to 20%). The evolution of recorded data on density (D_{PX}) of maize-soybean patties (V_{PX}), as function of percentage of the added hulled soy-flour (X%), can be described adequately by equation of the obtained trend curve, a polynomial function of degree 3 expressed by:

$$D_{PH} = -0.007X^3 + 0.013X^2 + 0.252X + 0.524$$

(g/cm³); R^2=0.994 (7-1)

As to densities of patties variants made up of unshelled soya flour (V_{PU}), they increase as the proportion of soybean added flour increases. Their growing rates range of 11.30% to 14.50% respectively with reference to density of patties witnesses. And the observed density behaviour can be adequately modelled by polynomial function expressed by:

$$D_{PU} = 0.007X^3 - 0.072X^2 - 0.036X + 0.734$$ (g/cm³);

R^2=0.990 (7-2)

At identical percentages of the used soy grains flour, densities of patties variants made of the hulled soy grains are lower than those provided by the unshelled soy grains. This observed difference, between these two categories of patties, appears to be highly related to presence (or absence) of hulls on the soy grains. It could, in principle, be attributed to idea that, the constitutive substance of hulls is much more dense compared to those of cotyledons and hypocotyl, both the other two remaining parts, after removal of the dandruff, at equal volume. The constitutive substances of soy grains hulls could also be the cause, for some moisture retention, when maintained unshelled, due to the noticed behaviour concerning the water content of the two kinds of patties. Therefore, it can also contribute to a narrowing or compression of corresponding patties' structure, in comparison to the witness (no soy added) variants of maize patties.

Volumetric expansion rates

The results volumetric expansion rate(E_r, %) of these tested variants of patties are shown on Figure 5.

Analysis of E_r data on Figure 5 clearly indicated that, all variants of maize-soy patties display higher expansion rates than witnesses: from 8.03 to 9.61% for hulled soy grains added variants and 7.73 to 8.56% for unshelled soy grainsones, against 7.66% for witnesses (Sanya *et al*., 2015). Moreover, volumetric expansion rate increases as added soybean content rises. In addition, soybean-flour included maize patties, outcome of hulled and torrefied beans, exhibit volumetric expansion rates relatively high, compared to those provided by variants of patties made of unshelled but also torrefied soy grains. Indeed, statistical exploration of the recorded data on evolution of volumetric expansion rate, in function of percentage of the added hulled soybean flour (X%), shows that it can be described adequately by obtained trend equation expressed by a simple power type function:

$$E_r = 7.5271 \cdot X^{0.1428};$$ R^2=0.95 (8-1)

As to variants of maize-soy patties added of unshelled soy grains flour (X%), behaviour of volumetric expansion rate, can adequately be described by polynomial type function:

$$E_r = 0.0457 \cdot X^2 - 0.0563 \cdot X + 7.664$$; R^2=0.981 (8-2)

We can then retain that, the presence of grains hulls in soy grains flour, seems, in some manner, disturb the full manifestation of phenomenon of patties' expansion. Expansion mechanism is linked with starch gelatinization which has probably been avoided. This can provide from constitutive material of soy grains hulls polysaccharides (cellulose, hemicelluloses and lignin) highly rich in arabinogalactans that form directly a barrier against air penetration and its distribution in the structure of patties dough. Due to presence of sugar (saccharose), see also of salt (sodium chloride), an insufficient supply in the required water for complete gelatinization of starch granules can happen (Sanya *et al*., 2016). This lack of water, preferentially favours polysaccharides–polysaccharides interactions which then best reinforced by those existing between polysaccharides contained in these maintained dandruffs on the variants of patties made of provided flour by entire soy-grains. Polysaccharides competition, with respect to water molecules, can be at the basis of patties' embrittlement. A thing that traduces their relative feeble volumetric expansion rate and justifies by this way these recorded high density values.

Breaking strength data

The obtained data from breaking strength measurements, on each of the nine studied patties variants (soy incorporated or not), are disclosed in form of bars charts on Figure 6.The first major result, for all of tested variants of maize-soy patties, resides in that, the recorded breaking strengths clearly show increase trend, as the soy grains flour content rises, whether this added flour has been provided by soy grains freed-of-dandruffs or by whole grains. The second main result is that, all variants of the maize-soy patties have shown higher values of breaking strength (70 to 140 N) than witnesses (60 to 65 N) corresponding respectively to strength increases, of 37.06 to 118.44% and 11.33 to 57.01%, report done in relation with the witnesses variant of patties(i.e. without soy). Some of maize-soy patties surprisingly display breaking strength values going broadly out of those furnished by peanut patties incorporated atcrude maize flour 84.65 – 92.64 N which have previously been characterized to be highly resistant and then not crunchiest (Sanya *et al*., 2015).

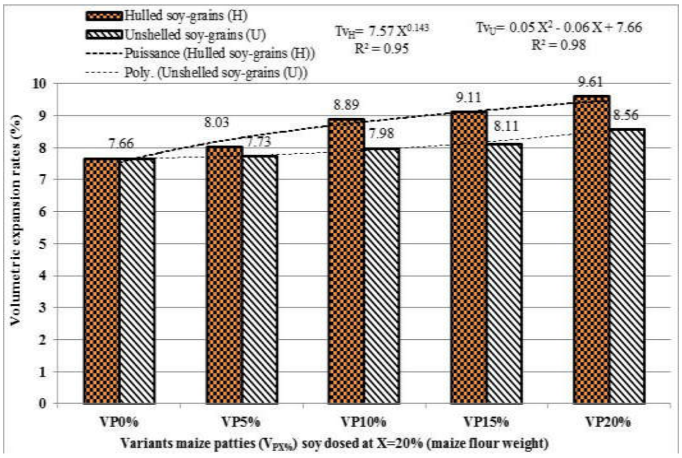

Figure 5.Volumetric expansion rates (E_r %) of maize patties' variants ($V_{PX\,\%}$)incorporated in torrefied soy-grains flour at X=0 % (witnesses) to X=20 %(maize flour weight)

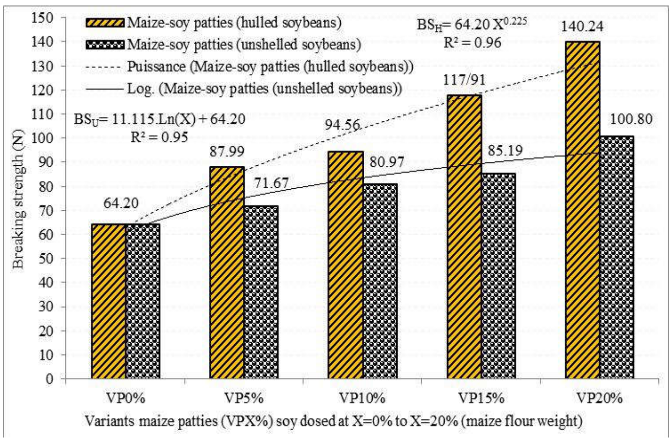

Figure 6. Breaking strength (N) of maize patties' variants (V_{PX} %) incorporated intorrefied soy-grains flour at X=0 % (witnesses) to X=20 % (maize flour weight) from TA-XT Analyser

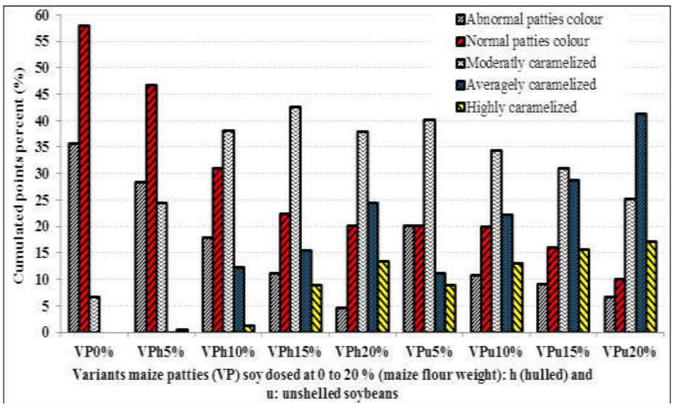

Figure 7. Estimated colour intensity, by interviewees, of maize patties ($V_{PX\%}$) incorporated of soy between X=0 % (witnesses) and X=20 % (maize weight) with reference to caramel

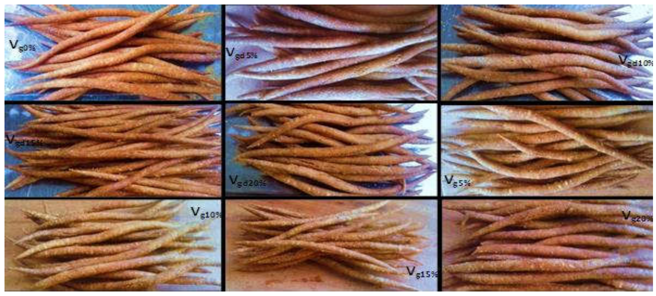

Figure 8. Photography of variants maize patties soy incorporated ($V_{PX\%}$) between X=0% (witnesses) and X=20 % (by maize flour weight)

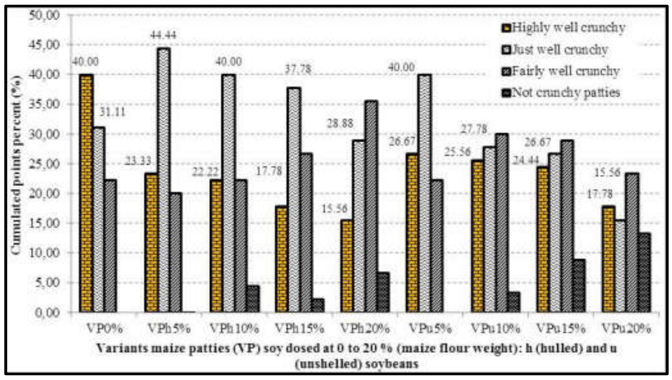

Figure 9. Estimated degree of crunchiness by interviewees of maize patties incorporated of soy ($V_{PX\%}$) between X=0 % (witnesses) and X=20 % (by maize flour weight)

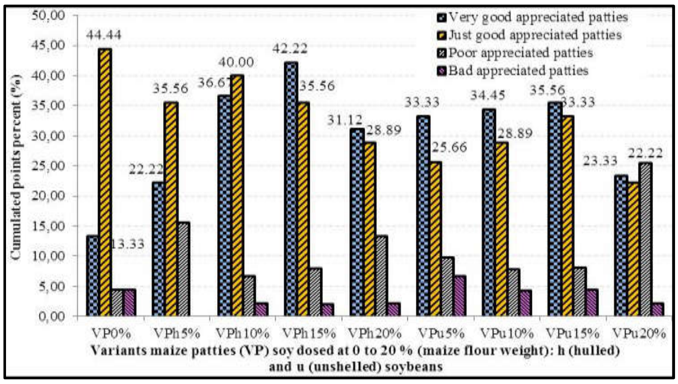

Figure10. General sensory appreciations (=taste +colour +odour +crunchiness) of maizepatties' variants incorporated of soy ($V_{PX\%}$) at X=0 % to X=20 % (by maize flourweight)

This means that, the constituents of soya, added to the maize patties formulation, contribute to the mechanical strengthening of their structure. The obtained third result is clearly displayed on Figure 6 where can be seen that, at identical added soy-flour percentages, confectioned maize patties variants using devoid-of-dandruffs soy-grains disclose higher breaking strengths than correspondents made of soy grains unfriended of their dandruffs.

Statistical exploration of the acquired data on the evolution of breaking strength (B_S), according to percentage of added flour of soy-grains (X%), shows two different behaviours relating to beared pre-treatment to used soy-grains. In case of not freed-of-dandruffs soy seeds, behaviour of patties breaking strength (B_{SPU}) can adequately be described by corresponding function to the trend equation expressed by the following logarithmic form:

$$B_{SPU} = 11.115 \cdot Ln(X) + 64.20 \text{(N)}; \quad R^2=0.95 \qquad (9\text{-}1)$$

As to variants of maize patties added of freed-of-dandruffs soy-flour i.e. shelled grains (X %), obtained breaking strength data (B_{SPH}) can adequately be described by a power type function:

$$B_{SPH} = 64.20 \cdot X^{0.225} \text{ (N)}; \quad R^2=0.96 \quad (9\text{-}2)$$

Sensory characteristics

Colour intensity of patties

The obtained data, from colour appreciation by respondents, on each of the nine variants of studied patties (soy incorporated or not), are those disclosed under charts bars form on Figure 7 which shows the proportions of cumulative points (in percent), following notations attributed by the forty five tasters. We can notice that witness variant of patties, i.e. that only made of pure maize flour, be distinguished properly for its normal clear color, in cumulating 57% points, over the nine (9) variants of maize-soy patties submitted to appraisal of interviewees. According to the collected data, it's followed, at 46.67% cumulative points, by variant of patties incorporated at 5% soy flour weight from devoid-of-dandruffs soy grains, and gradually reaching end, with 10.02% cumulative points using added soy flour at 20% weight content. In a global manner, these results let us concluding that, more the added soy-grains flour to maize one increases (from 0 to 20% in weight), more correspondent patties' colour is discarded from that of normal maize patties (i.e. without soy) and approaches that of caramelized colour, may the added soy flour coming from as freed-of-dandruffs soy grains or entire grains.In addition, with equal soy flour contents, maize-soy patties' variants made from the not decorticated soy-grains, exhibit a more pronounced caramelizing color than that for the elaborated patties using dandruffs-free soy-grains.

Patties crunchiness

The Figure 9 depicts the obtained results from analysis of tasting test sheets relating specifically to crunchiness of the studied maize patties variants made of soy grains (a quality criterion / sensation due to alveolar structure of a product submitted to multiple fractures during its chewing). The noticed great satisfaction, from realization of such crunchiness test, based on these 45 untrained respondents, resides at level of the recorded unanimity on the collected answers on the three criteria notations judged as priorities, mainly: 1-Highly well crunchy, 2-Just well crunchy, 3-Fairly well crunchy.

The displayed data on Figure 9 lead deducing that, from majority of respondents point of view, the more crunchiest patties variant is that made without any soy grains ($V_{P0\%}$) whilst variant incorporated at 20% soy grains ($V_{P20\%}$), labeled patties the minus. From then, the higher the content of soy-grains flour (whole or hulled grains made), the less crunchy are resultant maize-soy patties. This conclusion is attested by evolution of gray font bars on Figure 9.The found explanation attempt, to this recorded behaviour in crunchiness reduction for these soy incorporated maize patties, has a priori been imputed to their oil content increase, as proportion of soy-flour rises concurrently with their high fats content. However, complementary works remain necessary for best elucidating the mechanism at this level. Moreover, based on scoring criteria "Very well crunchy" or "Well crunchy", the data in Figure 9 show that, at identical levels of added soy-flour, patties variants made up using unshelled soy-grains are crunchier than those manufactured using hulled soy-beans. This seems here again to highlight the role of hulls maintain in that crunchiness sense. The hulls, by their presence on the soy-grains cotyledons, even weakened by torrefaction/roasting (Claude and Ubbin, 2006), probably retain elasticity-plasticity function, an important feature heavily involved in expansion mechanism of the extruded solid products and influencing their crunchiness (Duizer, 2001). The most crispy patties, elaborated maize-soy ones using unshelled soy-grains flour, are those having developed a certain correlation with the density increase. It's there, a contrary trend to that previously recorded relatively to caramelizing colour of the maize-soy patties, as if the strong caramelized colour displayed by a variant of patties may serve as indicator of the poor crunchiness. This result seems still paradox, considering that the observed increase might mean that the product structure had been tightened, unlike those for maize patties added of hulled soy-grains which density dropped with soy content increasing. It's rather thought obtaining a higher volume expansion rate. It has not been the case, probably due to another mechanism favoured by the soy-grains dandruffs. It's known that soy proteins have the particularity to gel and form adsorbed layers (Gosal et Ross-Murphy, 2000; Damodaran, 2004; Goldfein and Slavin, 2015), probably even better in interactions with these polysaccharides contained in soy-grains dandruffs (Kruif and Tuinier, 2001). The functional properties of soy proteins (concentrated in cotyledons) are such that a disruption in their native structure, made using a high heat supply (roasting or frying), may cause change in configuration and a new conformational equilibrium (Bauer *et al*., 2010). Moreover, crunchiness is deeply related to the development of air cells in resulting solid products of cooking process, cells essentially determined by starch's gelatinization. Only that, when added oil content, during manufacture of the solid products, increases, the used water amount by starch for gelatinization decreases and consequently, less the produced patties are alveolated (Zghal *et al*., 2005; Lassoued, 2005; Wagner, 2005; Qiang et Guelph, 2006). Moreover, in the process of trituration - extraction of soya oil, the seeds are usually stripped of their pellicles (Nihad, 2008). This proves that soy-grains dandruffs contain only very little oil, or not at all. Therefore, such a thing has oriented our explanation, relative to crustiness of the made patties using soy-grains not freed-of-dandruffs, towards this displayed elasticity behavior, undoubtedly derived from constitutive substances of their dandruffs. These results appear consistent and justify the superiority in recorded crustiness for witness patties variant, from previously reported various tests. Here again, mechanical testing results come confirming the obtained ones from sensory testing, in particular regarding crustiness of the formulated patties. It should also be underlined that similar behaviors have already been noticed in a conducted study on peanut patties incorporated of raw dry maize flour (Guédou, 2010; Sanya *et al*., 2015).

Tasters' general sensory appreciations

This effected general assessment accounts for combination of attractive settings as taste, colour, smell and the crunchiness of submitted patties to judgment of our respondents. The results on Figure 10 are those collected from recount sheets of tasting (remember, with untrained tasters). We've excluded the percentage of acquired notes relatively to the "indifferent appreciated patties" answer, this, in view of producing better readability of Figure. These data show that, the most overall appreciated variants of patties, by tasters are, in order of preference, those encoded respectively $V_{PH15\%}$, $V_{PH10\%}$, $V_{PU15\%}$, $V_{PU10\%}$, $V_{PU5\%}$ and $V_{PH20\%}$ where indexes H and U of V_{PH} and V_{PU} evoke the applied pre-treatments to soy grains (H=freed-of-dandruffs, U=not freed-of-dandruffs). In reality, most tasters found it difficult to make net distinction between the different variants of patties presented to them, regarding the overall quality assessment. These difficulties could be attributed to the fact that, the higher the proportion of soya flour increases in patties preparation, best become the taste, colour and smell, to the detriment of crispness which rather diminishes. This may explain the remarkable disaffection shown by the majority of the tasters, for the $V_{PU20\%}$ patties variant and also felt, but relatively less, in case of its homologous ($V_{PH20\%}$) incorporated of flour from freed-of-dandruffs soy grains. Ultimately, the data from tests on general quality assessment have provided us great satisfaction. Indeed, they've allowed us outlining pre-location of best quality variants of patties built of maize incorporated at soy. They are emerged in the range soy flour contents comprised between 10 and 15% (maize flour weight basis), the used soy grains freed of their dandruffs or not, but both torrefied. However, complementary study directed to deep optimization is required at this level.

Conclusion

This work has allowed exploring the induced effects, by the incorporation of torrefied soy grains flour, on some targeted characteristics of resulting patties, in order to assess their quality, in comparison with those from patties made of simple maize. For that, nine variants of patties were formulated, manufactured and submitted to study. The done physicomechanical analyses showed that, the higher the soy flour percentage in mixture with maize flour, the smaller, residual water content for derived patties from freed of dandruffs soy grains. It's not the case of the manufactured patties using not freed-of-dandruffs soy grains for which residual water content becomes higher as soy content increases. At contrary, opposite trend results were obtained for these studied patties bulk density which decreases with addition of flour from devoid-of-dandruffs soy grains and increases with flour from not freed-of-dandruffs grains. The volumetric expansion rate, in turn, increases with proportion of soy flour, whether the soy grains are freed of dandruffs or not, even if increase's intensity is more clearly perceptible when soy grains are skinned than not. Moreover, the realized sensory analysis, with the aid of regular consumers (even if they are untrained for it), has made us noticed that, increasing the soy flour rate intensifies the patties' caramelized colour and respectively reduces their degree of crispness and, consequently, the appreciation of patties overall quality. Considering consistency of results obtained till now, prospects of this study can then be directed towards multi-criteria optimization. This views improvement of the various quality characteristics of maize-soy patties, according to soy content, not to forget mentioning the influence of flavoured dough formulation, through constituents, structure and texture, on the crustiness of resultant patties.

REFERENCES

Adjadi, O. C.; Lokossou, O. G.; Azélokonon, C. D. ; Bankolé, A. K. A.; Djinadou, R. N.; Ahoyo-Adjovi, A. and Adjanohoun, A. 2015. Recueil de mets et de boissons à base de maïs consommés au Benin. INRAB & PPAAO/WAAPP /Benin, 155 p.

Afnor, 2010. Céréales et produits céréaliers - détermination de la teneur en eau: méthode de référence pratique. Norme NF-EN-ISO712 (V03-707).

Ahouansou, R.H. ; Aïssi, V. M. ; Sanya, E.A. ; Soumanou, M.M. 2012. Propriétés physique et mécanique des graines de pentadesmabutyracea produites au Bénin. *Journal of Applied Biosciences* 50: 3485- 3493. http://www.m.elewa. org, ISSN 1997-5902.

Anonyme, 2012. Valorisation des produits locaux: *face aux dé s, une diversité de solutions*. Grain de sel: la revue d'Inter-réseaux, Développement rural.

Bauer, W.J.;Badoud, R.;Löliger, J. 2010. Science et technologie des aliments: principes de chimie des constituants et de technologie des procédés. Éditions PPUR Presses polytechniques, ISBN:2880747546, 9782880747541.720 p.

Bergez, J-É and Abecassis, J. 2009. Les filières céréalières: Organisation et nouveaux défis. Editions Quae, 2759209768, 9782759209767.

Bhagwat, S. and Haytowitz, D.B. 2015. USDA Database for the Flavonoid Content of Selected Foods. Release 32.U.S Department of Agriculture, Agricultural Research Service. Nutrient Data Laboratory. http://www.ars.usda.gov/ nutrientdata/flav.

Branger, A. ; Richer, M-M. and Roustel, S. 2009. Alimentation, processus technologiques et contrôles. EducAgri Editions. 199 p.

Brink, M. and Belay, G. 2006. Céréales et légumes secs. Vol. 1. *Ressources végétales de l'Afrique tropicale*, (Editions GJH Grubben). Nature, PROTA, 327 p.

Burgess, A. 2005. Guide de nutrition familiale. Food and Agriculture Organization of the United Nations. *Food & Agriculture Org.*, 134 p.

Carrareto M. 2005. Histoire de maïs d'une divinité Amérindienne à ses avatars transgéniques. C.T.H.S, 56 p.

Chanussot, F. 2008. Lécithine, métabolisme et nutrition. Editions Lavoisier, 15 Avr. 500 p.

Charreau, V.; Etienne, N. and Ingargiola E. 2013. À la découverte des aliments: tester, comprendre et partager les sciences de l'alimentation. Educagri Editions, 355 p.

CIC., 2016. Conseil International des Céréales: Bilans céréaliers : Campagne 2014/2015 et Perspectives 2015/2016. Editions FranceAgriMer. pp: 4-55.

Claude, J. and Ubbin, J. 2006. Thermal Degradation of Carbohydrate Polymers in Amorphous States: A Physical Study including Colorimetry. *Food Chem.,* 96: 402-410.

Damodaran, S. 2004. Adsorbed layers formed from mixtures of proteins, *Current Opinion in Colloid & Interface Science*, 9, 328-339.

Daniel, C. and Roudot, A-C. 2007. La terminologie de la texture des aliments. Meta : *Journal des traducteurs*, Vol. 52, n°2, juin, pp: 342-351. DOI: 10.7202/016075ar.

De Reynal, B. 2009. Additifs et auxiliaires de fabrication dans les industries agroalimentaires. 4e Edition. Lavoisier, 3 Juil., 736 p.

Demarquoy, J. 2014. Le Dictionnaire de la nutrition. *Jouvence Santé*, 26 Mars, 576 p.

Duizer L. 2001. A review of acoustic research for studying the sensory perception of crisp, crunchy and crackly textures.*Trends in Food Science and Technology*, Vol.12, pp: 17–24.

Fao, 2010. Système d'Information des Ressources en Alimentation Animale. *Food and Agriculture Organization*. FAOSTAT.

FaoStat, 2015. World Crops Production: soybeans production quantity for 2014. Food and Agriculture Organization of the United Nations Statistics Division. Countries/ Territorials Notes. http://faostat3.fao.org/download/ Q/QC/ E.

Fillion, L. and Kilcast D. 2002. Consumer Perception of Crispness and Crunchiness in Fruits and Vegetables. *Food Quality and Preference 13*, pp. 23-29.

Goldfein, K.R and Slavin J.L. 2015. Why Sugar Is Added to Food: Food Science 101. Comprehensive Reviews in Food Science and Food Safety, 14(5): 644-656.

Gosal, W.S. and Ross-Murphy, S.B. 2000. Globular protein gelation, *Current Opinion in Colloid & Interface Science*, 5, 188-194.

Guédou, G. 2010. Caractérisation physico mécanique des galettes béninoises à base de farines d'arachides et de maïs: mise au point et validation d'un protocole expérimental. Mémoire de DEA-SPI. Université d'Abomey-Calavi, 103p.

Guéguen J. and DucG. 2008. La filière protéagineuse: Quels défis? Quae, 2759212513, 9782759212514.

Guillard, V.; Bourlieu, C. and Gontard, N. 2013. Food Structure and Moisture Transfer*: A* Modeling Approach. *Springer Briefs. Food Health and Nutrition Series*, VII. 60p.

Insae, 2013. Extrait des Statistiques Economiques: Les treize filières agricoles prioritaires au Bénin. Institut National de la Statistique et de l'Analyse Economique. Bénin. www.insae-bj.org/production-agricole/html visité le 10/09/2015 à 11 h 32min.

Iwuoha, I.C. 2004. Comparative evaluation of physicochemical qualities of flours from steam-processed yam tubers. *Food Chem.*, *85*: 541–551.

Kruif C.G. and Tuinier R. 2001. Polysaccharid protein interactions. *Food Hydro*., 15, 555-563.

Lassoued, N. 2005. Structure alvéolaire des produits céréaliers de cuisson en lien avec les propriétés rhéologiques et thermiques de la pâte : effet de la composition. *Sciences du Vivant* [q-bio]. ENSIA (AgroParisTech). Français. NNT: EIAA0155. pastel-00003695.

Latham, M.C. 2001. Food and Agriculture Organization of the United Nations.*Food & Agriculture Org.*, 520 p.

Leray C. 2013. Les lipides – nutrition et santé. Editions Lavoisier, 4 Avr. 334 p.

Mérie D. 2011. Les Associations Alimentaires Compatibles: Tome 1.Editions: Fernand Lanore, 320 p. ISBN: 2851576321, 9782851576323.

Nihad, N. 2008. Suivi et comparaison des paramètres physico-chimiques de l'huile de soja raffiné chimiquement et enzymatiquement produites par Cevital. Mémoire de fin d'Etude. Université Abderrahamane Mira–Bejaïa, Algérie, 117 p.

Oluwole, F.A, Abdulrahim, A.T. and Alalere R.K.2007. Evaluation of some centrifugal Impaction Devices for Shelling Bambara Groundnut. *Agricultural Engineering International: the CIGR E-journal*. Manuscript PM 07007. Vol. IX. 14p.

Paulet, J.V. 2010. Amélioration des procédés traditionnels de transformation de certains oléagineux et du manioc. Division Nutrition & Alimentation, FAO. Editions FaoStat. 53 p.

Qiang, L. and Guelph, A.A.F.C. 2006. Caractérisation *in vivo* et *in vitro* des amidons résistants de maïs et de produits de maïs ontariens comme ingrédients alimentaires fonctionnels à valeur ajoutée. http://www.omafra.gov.on.ca /french/research/htm.

Rahman, M.S. and Al-Farsi S.A. 2005. Instrumental texture profile analysis (TPA) of date flesh as a function of moisture content. *J. Food Eng.,* 66: 505–511.

Roberfroid, M.B; Coxam,V. and Delzenne, N. 2008. Aliments fonctionnels. Lavoisier, 2e Edition, Paris (France), 30 Avr., 1088 p.

Sanya, E.A.;Ahouannou, C.;Chaffa, G. and Ahouansou R. 2015. Effects of torrefactionon some physicomechanical and organoleptic characteristics of maize flour blended peanut patties rolled into sticks in Benin. *Int. J. Biol. Chem. Sci.*, 9(3): 1440-1458.

Sanya, E.A., Ahouannou, C., Chaffa, G. and Soumanou, M.M. 2013. Effects of added maize flour on physicomechanical properties of Benin patties made of defatted dough of groundnut seeds "*Arachishypogaea*". *Int. J. Current Research*, Vol.5, n°02. pp: 212-218.

Sanya, E.A., Ahouansou. H.R.; Bagan, G. and Vianou, A. 2009. Effets du débit d'alimentation et de la vitesse de grille motrice sur les performances d'une décortiqueuse de graines de néré «*Parkia biglobosa*». *J. Rech. Sci. Univ. Lomé (Togo) Série A*. 10(1), pp: 1-11.

Sanya, E.A; Fagla, Z.F.B; Ahouansou, R.H. and Sanya, A.K.C. 2016.Effects of the added sugar on some physicomechanical and sensory properties of maize patties (*ike/klaklou)* rolled in-sticks-like of Benin. *Research Journal of Engineering Sciences (RJES).*Vol. 5, n°2; pp: 1-16. ISSN: 2278 9472. www.isca.in

Schneider, A. and Huyghe C. 2015. Les légumineuses pour des systèmes agricoles *et al*imentaires. Editions Quae, 512 p.

Usda-Ars, 2000. U.S. Department of Agriculture, Agricultural Research Service. Nutritive Value of Foods: Composition of Foods: Raw, Processed, Prepared. Home and Garden Bulletin No. 72 (HG-72). USDA National Nutrient Database for Standard Reference, Release 13: 7-39. http://www.ars.usda.gov/nuteintdata.

Usda-Ars, 2014.US Department of Agriculture, Agricultural Research Service.USDA Food and Nutrient Database for Dietary Studies 2011-2012. Food Surveys Res. http:// www.ars.usda.gov/SP2User Files/Place/80400530/pdf/fndds/fndds.

Usda-Ars, 2015.US Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. USDA National Nutrient Database for Standard Reference, Release 28 Current: September. http://www.ars.usda.gov/ Services/docs.htm?docid=8964

Valles, P.B. ;Roudaut, G. ; Dacremont, C. ; Le Meste, M. and Mitchell R. 2000. Understanding the texture of low moisture cereal products: part I - Mechanical and sensory measurements of crispness. *J. Sci. Food Agr.*,80: 1679-1685.

Wagner, H.M. 2005. Suivi local et dynamique par IRM lors de la cuisson du pain et étude des mécanismes contrôlant la mise en place de la structure alvéolaire. *Thèse de doctorat.* ENSIA, France, 225p.

Yé, S. ; Lebeau, F. ; Wathelet, J-P ;Leemans, V. and Destain, M-F. 2007. Étude des paramètres opératoires de pressage mécanique des amandes de *Vitellaria paradoxa* Gaertn C.F. (karité). *Biotechnol. Agron. Soc. Environ.* 11(4), pp: 267–273.

Zghal, M.C., Scanlon, M.G., Sapirstein, H.D.2002. Cellular structure of bread crumb and its influence on mechanical properties. *Journal of Cereal Science,* 36, 167-

****