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RESEARCH ARTICLE

EXPERIMENTAL AND BET PREDICTION OF MONOLAYER MOISTURE OF CAMEROONIAN TARO (*COLOCASIA ESCULENTA*) POWDER AND EFFECT ON THE ACCEPTANCE OF RECONSTITUTED ACHU (TARO PASTE)

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Abstract: The aim of this study was to produce taro flour with good storages characteristics for the preparation of achu. To attend this objective, the monolayer moisture of taro powder was investigated using the BET predictive model and experimentally using Carbonyl as marker degradation of the powder. Powders were then produced by drying up to the monolayer moisture (7-8%), above (10%) and under (5-6) this monolayer moisture, before being reconstituted into achu which were submitted for sensory evaluation. The results revealed that moisture content varied with water activity in the range 1 to 53% according to the BET sorption model. The monolayer moisture content determined was 6.8% while carbonyl curve exhibited a lower value at moisture content 7.2%. The acceptability of taro paste made from taro powders was highly influenced by the end-drying moisture content. Taro powder with moisture content situated between 7-8% was most appreciated. When this powder was submitted for a consumption test, all consumers were ready to buy the flour, but the psychological price seems to be highly influenced by the incomes of households. This study showed that carbonyls level in taro is a potential marker for the degradation of taro flour during processing and storage. In conclusion the monolayer moisture content of taro powder could be determined by the BET model, but this need to be confirmed by product degradation such as carbonyls in the case of taro powder. The flour obtained at a_w near of the monolayer moisture produced the achu with a good acceptability.

Keys words: taro flour, taro paste, carbonyls, monolayer moisture, consumer test.

Introduction

Earlier studies carried out on taro had shown that water activity (a_w) is one of the major important parameters in the drying and the storage of taro flour (Nip, 1997; Njintang *et al.*, 2007). During drying and storage, molecules in foods undergo chemical modifications which affect the nutritional and organoleptic qualities (colour, flavour and texture changes) (Gardner, 1979). Many factors such as oxygen, light, heat treatment water activity and storage conditions, can influence the auto oxidation of food products (Cheftel, 1977). The regulation of this phenomenon, through establishment of sorption isotherms has led to the control of such reactions which contribute to oxidation (Kinsella and Foch, 1986).

Sorption isotherms have a great importance in predicting food behaviour during treatment and storage (Cheftel, 1977). Using many theorical models (BET or GAB), it is possible to obtain optimal condition parameter in which flour can be stored. Indeed, the derivation of equation of the model can lead to the determination of optimal moisture contents. In fact, it is considered that, the high stability of the flour is associated to monomolecular water layer (Kinsella and Foch, 1986). Many studies were made on the application of theorical models to predict many phenomena on the stability of dried products (Njintang, 2003; Medoua, 2005), but they have not been confirmed on precooked taro flour. In order to obtain the most favourable degree of dehydration for improved taro flour stability, the present study based on the sorption isotherm was carried out. Although many studies assumed that the best drying and storage conditions of foods are at the monomolecular moisture content (Genot, 1986), this cannot be testified unless it has been proved experimentally that degradation is less in that condition (Gardner, 1979). In this respect we equally evaluated the levels of degraded compound as molecular markers (issued either from the lipid or protein auto oxidation or the Maillard reaction) at different relative moisture levels in order to ascertain experimentally the stability of the product (Gardner, 1979).

The study of compound degradation during processing is possible by many methods and can be divided into two groups. The first group usually used or global indicator is characterised by their specificity (lipid oxidation or maillard reactions) and the second group is characterised by their lack of specificity (determination of carbonyl groups). Sometimes, all those methods are not easy to realise, because of the difficulties to adapt them or the sophistication and expensive equipment needed. To overcome this difficulty two methods seem interesting: the first one is the method based on the determination of thiobarbituric acid reactive substances (TABRS). This method is characterised by the determination of malonaldehyde (Genot, 1986). The second method concerns the determination of carbonyls using de 2.4. dinitrophenylhydrazine (2.4. DNPH). In fact, carbonyls belong to the chemical compound class also including aldehydes and ketones. These compounds are derived from lipid oxidation on one hand (Gardner, 1987; Halliwell and Gutteridge, 1990) and protein oxidation on the other hand. As of now, to the best of our knowledge, such study making use of predicting models and experimental markers have not yet, or less, been applied to food systems including taro.

The present study consists to produce taro flour with high storage stability and good acceptability. To attend this, the study will focus firstly on establishing a method of determining a most favourable drying moisture content of taro powder using biochemical indicators, Secondly on comparing the moisture content determined through the biomarkers and that from the BET theoretical model, and thirdly on assessing the acceptability of the powders at these drying conditions.

Materials and methods

Materials

The cormels of red variety of *Colocasia esculenta* corms, locally called «Ibo coco» used in this study were freshly harvested from a farm in Bini town (Ngaoundere-Cameroon). Cormels were thoroughly washed in clean water and kept at 4°C until required for use.

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Methods

Cooking of tubers and powder production

Cormels were plunged in water 1:3 (w/v) contained in a 12L volumetric pressure cooker and cooking carried out for 15 min (time determined after trials necessary to cook cormels under pressure). Cooked tubers were then peeled off, cut into cubes (1x1x1cm approximately), freeze-dried at –40 degrees for 3 days and milled into powders in a hammer milling machine to pass a sieve size of 500 µm.

Proximate composition of powder

Powders were analysed for moisture (air oven method), fat (Soxhlet) and ash (direct method) contents, following AACC standard methods (1990). Total protein (Nx6.25) was analysed using approved methods of Kjeldahl (AACC, 1990) in semi-automatic machine (GEHARDT, Paris, France). The total resistant starch content was analysed essentially as described by Goni *et al.* (1996). Available carbohydrate was determined essentially as described earlier (Njintang *et al.*, 2001). Precisely, 1.5 g of flour sample was suspended in 10 mL of 1.5N H_2SO_4 and heated for 20 min after which 10 mL of a 10% NaOH solution was added to the mixture and the volume adjusted to 100 mL. The solution obtained was used for the spectrophotometric determination of reducing sugars generated from the hydrolysis of carbohydrates (Bernfeld, 1955). In this method a 0.25 mL solution was mixed with 0.5 mL distilled water and 0.25 mL of a dinitrosalicylic acid solution, and the mixture heated in a water-bath for 5 min at boiling temperature. During heating, alkaline 3,5-dinitrosalicylic acid (DNS) forms a red-brown reduction product, 3 amino-5-nitrosalicylic acid, in the presence of a reducing sugar. The intensity of the colour developed at 540 nm is proportional to the quantity of reducing sugars.

Accelerated storage

Powders (2g) samples were weighed precisely in a Petri box and then sealed hermetically in a shell together with saturated salts. The saturated salts silica gel (Si), lithium chloride (ClLi), potassium acetate ($C_2H_3KO_2$), magnesium chloride ($MgCl_2$) and magnesium nitrate ($Mg(NO_3)_2$), were used to give moisture contents of 7, 11, 23, 33 and 53%, respectively (Stapelfeidt *et al.*, 1997). The shells were then stored in a tank at 45 ± 1 °C for 20 days. Two samples were taken at intervals of ten days during storage. The flours were weighed to measure the adsorbed moisture content.

Determination of Monolayer moisture content using the Brunauer-Emmet-Teller (BET) predicting model

The linearised BET theoretical model used in this case is represented by the following equation:

$$\frac{aw}{(1-aw)} = \frac{1}{M.C} + \frac{aw(C-1)}{M.C} \quad (1)$$

Where M is the monolayer value, $C = K.e^{\frac{QS}{RT}}$ and QS is the heat of absorption.

The BET model was chosen as it is better suited to water activities less than 0.5 (O'Connor and O'Brien, 1994).

Determination of carbonyls contents

The powder (1 g) was dissolved in 100 mL distilled water at 40 °C and stirred by a small magnetised bar for 10 min. An aliquot (1 mL) of the mixture was placed in a screw-top tube of 20 mL and 1 mL of 2.4 dinitrophenylhydrazine (2.4 DNPH, WVR international, France) solution was added. The solutions were vortexed for 30 s and then left to fall downward for 5 min. This stage of the process was repeated twice and 1.1 mL of 10% trichloroacetic acid was added to the mixture, thus precipitating the yellow-coloured complex (carbonyls – 2.4 DNPH). After centrifugation at 1000 rpm for 10 min at room temperature, the residue was solubilised in 10 mL of urea 8 $mol.L^{-1}$ and the absorbance determined at 370°C using quartz curvet in a spectrophotometer Spectronic 2PC Genesys against a blank made of urea 8 $mol.L^{-1.}$ The results were represented in optical density equivalent per mg protein ($OD.mg^{-1}$ of protein).

Determination of total malondialdehyde (MDA)

The analysis of the reactive substance with thiobarbituric acid was done by the method of Genot, 1996. Thiobarbituric acid (TBA) reacts with the malondialdehyde (MDA) to form a pink coloured complex possessing a maximum absorption peack at a wavelength of 532 nm. In this respect, 2g of sample were weighed in 25 mL test tubes. In

order to limit the oxidization, the tubes were cooled in crushed ice and 100 µL of TBH (1mg/mL in the ethanol) and 16 mL of 5% (w/v) trichloroacetic acid (TCA) were added. The mixture was homogenized 3 times at a speed of about 20 000 rpm for 15 sec using a mixer (Janke and Kunkel, Germany) before being centrifuged (15 min, 5000g, Hettich Universal 320R). The supernatant was collected and 2 mL, thiobarbituric acid (2 mL) was added to it and the mixture incubated in a waterbath at 70°C for 30 min. After this, the tubes were then cooled in water bath at room temperature and absorbance read at 532 nm against a blank tube made of 2 mL of thiobarbituric acid and 2 mL of trichloroacetic acid solutions. The total malonaldehyde were given by the following equation:

$$mg\ equivalent\ MDA = \frac{2 \times A_{532} \times V_{TCA} \times M \times 10^{-2}}{1.56 \times m} \quad (2)$$

where V_{TCA} is the volume of TCA (16 mL), m is the weight of analysed sample (g) and M is the molecular weight of malonaldehyde (72 g.mol^{-1})

Production of taro powders using a freeze drying and evaluation of acceptability of achu (taro paste)

Based on optimal conditions of drying determined by the adsorption isotherm and biomarkers measurements, cooked taro slices were dried in electric dryer (ventilation speed at maximum) at three different moisture contents (10-12%, 7-8% and 5-6%) and ground in a hammer mill equipped with a sieve mesh 500 µm. The taro paste was prepared by reconstituting 100 grams of taro powder with boiling water so as to achieve a moisture content of 80 % (wet basis). The suspension was then mixed for 10 min and a homogeneous paste called achu was obtained. A study of the acceptability of appearance, texture, smell, taste and overall acceptability was conducted by a panel of 53 students served over pasta with or without sauce in random order. A follow-up pilot consumption study on 100 families randomly chosen among urban populations in Ngaoundere Town, Cameroon, was then carried out to evaluate the acceptability of the powder (500g package for each family).

Results and discussion

Chemical composition of taro powder

The biochemical composition of taro powder at t_0 (initial time of storage) is represented in Table 1. The results show a classical nutrient distribution of crops. Carbohydrate had the highest value while fat had the lowest value (0.93%). The available carbohydrate values obtained in this work were higher than those found in other works (Nip, 1997; Njintang, 2003; Njintang and Mbofung, 2003b). This difference is probably due to the difference in drying method. In fact, it has been demonstrated that freeze drying induces no chemical changes in foods and hence improve biochemical and organoleptic characteristics of food products (Cheftel, 1977). This was demonstrated by Efstathiou *et al.* (2002) on freeze dried milk powder. The improved quality of taro flour by freeze drying is chosen in this study in order to avoid any change due to drying, and control the mechanism induced by storing or drying at a given temperature.

Table 1. *Chemical composition of freeze dried taro flour*

Moisture (g/100gd.b)	Digestible starch (g/100gd.b)	Resistant starch (g/100gd.b)	Protein (g/100g d.b)	Fat (g/100gd.b)
7.21±0.95^{d}	80.39±4.9^{e}	6.07±0.3^{c}	2.63±0.18^{b}	0.93±0.05^{a}

Means±standard deviation

The means on the same line followed by same letter are not significantly different at probability level 0.05.

Adsorption isotherm of freeze dried precooked taro powder

Figure 1 illustrates the adsorption isotherm of freeze dried taro powder. At a_w between 0.07 and 0.33 taro powder adsorb water spontaneously after which a stagnation in the moisture content was observed up to a_w 0.53. At a_w of 0.33, moisture content of flour was situated between 7 and 7.5 g H_2O/100 g d.b. This value was higher than the result (4 gH_2O/100 g d.b) reported earlier on solar dried taro powder (Aboubakar, 2008).

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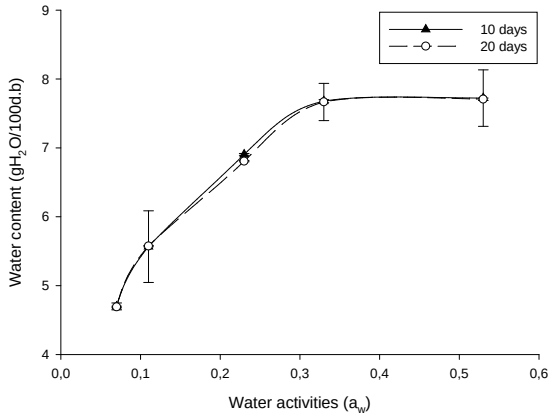

Figure 1. *Adsorption isotherm of freeze dried taro flour*

This observation could be explained by the fact that during freeze drying, all the properties of food are preserved (Cheftel, 1977). The benefit of freeze drying of taro had also been put into evidence by Njintang (2003), and this justified its use in this experiment, in other to avoid any deterioration before storage.

The monolayer moisture content was determined from the desorption isotherm using the BET theoretical model. As shown in figure 2, a linear relationship was observed in conformity with the BET model between the a_w range 0 and 0.53.

Carbonyls content at variable a_w

The variation of carbonyls content at variable water activity (a_w) after 20 days of storage is shown in Figure 3. The graph reveals that there was no proportional reaction between Carbonyls content and a_w with the curve running though a minimum and a maximum value. The minimum of the curve was the point corresponding to the lowest rate of carbonyls content (6.14 and 6.6 Units DO/100g proteins), situated around a_w values of 0.07 or 0.26. Over this step, the carbonyl content increased. This result suggested that, the optimum water activity for the production and storage of taro powder, necessary for lower carbonyl content was around a_w of 0.07 and 0.26. These values were comparable to 0.2±0.03 reported for freeze dried milk powder (Efstathiou *et al.*, 2002). Similarly to the result reported here, this author does not find a proportional relationship between carbonyl content and a_w.

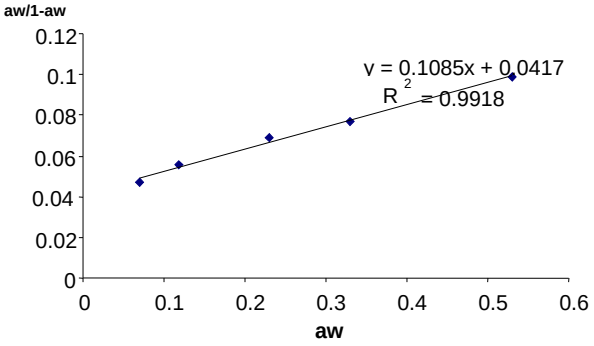

Figure 2. *Linearized curve of the desorption isotherm of taro powder using the BET Equation model*

After calculation, the result of this study showed that the monolayer moisture value of freeze dried taro powder, after 20 days storage corresponds to 6.8 g H_2O/100 g d.b. This value was lower that reported by Efstathiou *et al.* (2002) on freeze dried milk powder (8.20 g H_2O/100 g d.b). These authors explained the higher value of monolayer moisture of foods systems by the difference in their biochemical components and reactivity. This explanation seems logical and could corroborate with our findings by the fact that, the proteins and fats contents of our sample were very weak compared to their substrate, milk powder.

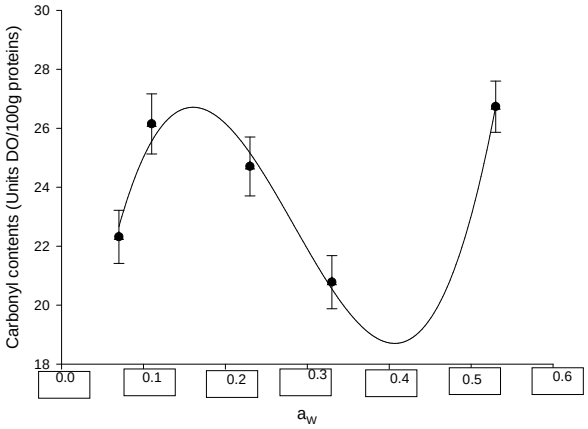

Figure 3. *Variation of carbonyls content as a function of water activity*

The monolayer layer moisture content as determined by the BET theoretical model and that deriving from the biomarker carbonyls were compared in a joined plot as shown in Figure 4.

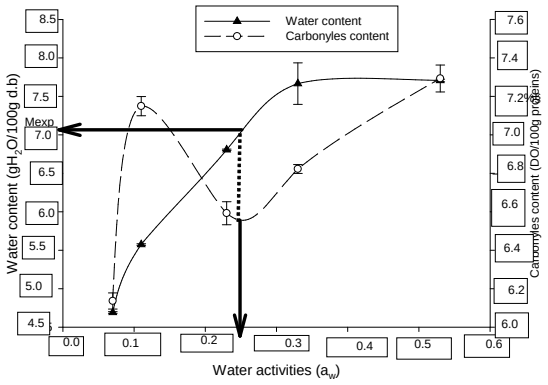

Figure 4. *Experimental determination of monolayer value of freeze dried taro flour after 20 days*

The dotted lines, for the total MDA curve evolution and continuous lines for the evolution of carbonyls, enables us to situate the moisture levels on the deterioration curve of the product.

Influence of the end drying moisture content on the acceptability of achu reconstituted from taro powder

Results of the sensory evaluation are summarised in Table 2.

The graph of the evolution of the total MDA and carbonyls of freeze dried taro powder (Figure 5) represents the same outline as the quantities in optimal a_w (0.26 and 0.32 optimal a_w for the graphs of evolution of carbonyls and total MDA respectively).

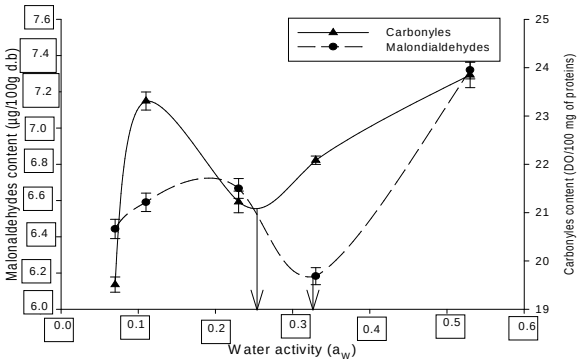

Figure 5. *Variation of malonaldehydes and carbonyls as a function of water activities after 20 days of storage*

Statistical analysis revealed that moisture content significantly influenced the acceptability of appearance, ($p = 0.010$), flavour ($p = 0.04$) and texture ($p = 0.003$) while the acceptability of colour, the general acceptability with or without the sauce does not vary significantly.

Table 2. *Influence of end drying water content on the sensory acceptability of achu*

Achu*	Aspect	Colour	Texture	Flavor	General acceptability with sauce	General acceptability without sauce
5-6%	5.00±1.78 ^{ab}	4.92±1.04 ^{ab}	5.62±1.71 ^{c}	3.54±1.66 ^{c}	3.62±2.26 ^{b}	4.77±2.74 ^{b}
7-8%	6.00±1.58 ^{a}	5.69±1.70 ^{a}	5.69±1.38 ^{bc}	5.31±1.65 ^{b}	4.85±2.15 ^{b}	5.75±2.27 ^{b}
T. Achu	5.85±2.00 ^{a}	4.00±1.35 ^{b}	6.92±1.93 ^{ab}	6.92±1.32 ^{a}	6.73±1.36 ^{a}	7.69±1.38 ^{a}
10-11%	3.46±2.54 ^{b}	5.46±1.71 ^{a}	7.54±1.33 ^{a}	4.92±2.06 ^{b}	5.00±2.24 ^{b}	5.50±1.80 ^{b}

Means±standard deviation
The means on the same column followed by same letter are not significantly different at probability level 0.05.
* achu were made either from taro powder of end drying moisture content given in the table while T. achu is traditionally made achu.

In general achu prepared from taro powder of moisture content 7-8% was most accepted for its appearance, flavour as well as its texture. When the acceptability of reconstituted achu was compared to that prepared traditionally, achu made from the flour was less scored because of the presence of particles in the achu reconstituted from flour. In this respect the panel recommended sieving of flour to remove particles and fibers.

The recommendation of the sensory panel was taken into consideration to improve the quality of the powder which was used for the consumption test by families of variable social strata. The socio-economic characteristics of consumers are presented in Table 3 and accordingly all academic levels and occupational categories are fairly represented.

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Table 3. *Socio-economic characteristics of consumers*

Age	Academic	Marital statut	Monthly income	Occupational Category
age<35 52.6%	Primary 10.5%	Wedded 84.2%	<100 000 78.9%	Housewife 47.4%
age<55 47.8%	Secondary 57.9%	Single 15.8%	<200 000 5.3%	Worker 31.6%
	University 31.6%		>200 000 15.8%	Frames 21.1%

According to our results, all participants of the test knew and liked the tuber and the paste derived from it, achu. Among them 52.6% consumed achu less than 7 times per month, 15.8% consumed 7-10 times per month, while 31.6% consumed more than 10 times per month. These observations mean that the panel selected was used to taro and achu. Regarding the achu, all panellists knew how to prepare it and all the constraints associated with. Concerning the constraints in achu preparation, 84.2% consider achu labour intensive, 10.5% time consuming while 10.5% directed to other constraints. In fact in the traditional procedure of taro preparation, the corms and cormels are first cooked for 1 to 8 hours depending on the variety and the energy used, and then peeled and pounded in a mortar to a smooth and homogeneous paste called achu. Achu is usually served with a yellow sauce, an alkaline emulsion of red palm oil containing 10 to 20 spices and meat. The observations made by the panel confirmed the initial problem that led to research on taro powder currently underway. All the consumers are unanimous that an alternative way of preparation of achu, which is less painful and less time consuming could foster consumption and increased incomes for producers.

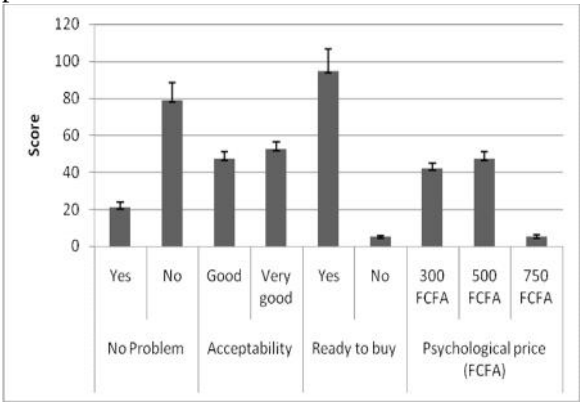

Figure 6. *Score of the acceptability of taro powder by households in Ngaoundere town*

When powders produced from a_w near the monolayer moisture value (7-8%) was offered to consumers for the preparation and consumption of achu in their family, over 3/4 recognized having no problem for its use (Figure 6).

These results suggest that the use of taro flour, using the reconstitution manuel, by some households will be facilitated by the training sessions. Results on the acceptability of achu revealed that more than 52.63% like very much the achu they made from taro powder while 47.37% just like it. Indeed the result obtained from a population that knows and frequently use achu shows the good properties of the powder that need to be standardized. Obviously most (95%) of the consumers would buy the powder if it is marketed (Figure 6). The reluctance of 5% of consumers is related to the depreciation of their dish which is considered as a traditional symbol.

But probably with social development, these products will fit well also among the most reluctant. One problem that that need attention with the marketing of the powder is the psychological price (300-500 FCFA for 250 g) which is under the operating account evaluated at 550 FCFA (Njintang *et al.*, 2007). This result shows that the low purchasing power of consumers is the highest constraint that could hamper the market development of taro powder.

Conclusions

The monolayer moisture of taro powder could be analyzed by the global biochemical indicator determination. The method using carbonyls as indicators of deterioration permits a determination of the monolayer moisture content. The theoretical and experimental values of monolayer moisture contents are closer. Water activity for less formation of carbonyls is lower (0.26) than that for MDA formation (0.32). The monolayer value of taro powder is around 7 and 8 %. The preparation of achu reconstituted from taro powder, a less painful alternative is appreciated by all strata of the population under study.

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References

AACC, 1990. American Association of Cereal Chemists. Approved methods of the AACC (7th ed.). St. Paul, MN.

Aboubakar, Njintang, Y.N., Scher, J. and Mbofung, C.M.F., 2008. Physicochemical, thermal properties and microstructure of six varieties of taro (*Colocasia esculenta* L. Schott) flours and starches, *Journal of Food Engineering*, 85: 294-305.

Bernfeld, P., 1955. Amylases, α and β. Methods in Enzymology, 1: 149

Cheftel J.C., 1977. Introduction à la biochimie et technologie des aliments, *Lavoisier, Tec and Doc*, Paris, France, pp. 3–31.

Efstathiou T., Feuardent C., Méjean S. and Schuck P., 2002.The use of carbonyl analysis to follow the main reactions involved in the process of deterioration of dehydrated dairy products: prediction of most favorable degree of dehydration. *Lait* 82, 423–439.

Gardner H.W., 1979. Lipid hydroperoxide reactivity with proteins and amino acid: a review, *J. Agric. Food Chem*. 27 220–229.

Genot C., 1996. Some factors influencing TBA test. Report of diet-ox project (AIRIII-CT-92-1577). Gardner H.W., 1987. Reactions of hydroperoxides – Products of high molecular weight, in: Chan H.W.S. (Ed.), Autoxidation of unsaturated lipids, Academic Press, London, UK, pp. 51–93.

Halliwell B., Gutteridge J.M.C., 1990. Role of free radicals and catalytic metal ions in human disease: An overview, in: Packer L., Glazer A.N. (Eds.), Oxygen radicals in biological systems, Methods in Enzymology, Academic Press, San Diego, USA, Vol. 186, pp. 1–85.

Goni L., Garcia-Diz, Manas E. and Saura C. F., 1996. Analysis of resistant starch; a method for foods and food products. *Food Chemistry*. 56(4): 455–459.

Kinsella J.E.and Fox P.F., 1986. Water sorption by proteins, CRC Crit. *Rev. Food Sci. Nutr*. 24 ,91–13.

Medoua G., 2005. Nutritional and technological potentials of cured tubers yam (*Dioscorea dumetorum* (Kunth) pax). PhD thesis, University of Ngaoundéré, Cameroun.

Nip W.K., 1997. Taro: in Processing Vegetables, Science and Technology. Eds D.S. Smith, J.N. Cash, W.K. Nip and Y.H. Hui. Technomic Publishing CO., Inc, Pensylvania, USA pp 355-387.

Njintang Y.N. and Mbofung C.M.F., 2003. Development of taro (*Colocasia esculenta* (L) Schott) flour as an ingredient in food processing: effect of gelatinisation and drying temperature on the dehydration kinetics and colour of flour, *Journal of Food Engineering* 58, pp. 259–265.

Njintang Y.N. Mbofung C.M.F. and Kesteloot, R., 2007. Multivariate analysis of the effect of drying method and particle size of flour on the instrumental texture characteristics of paste made from two varieties of taro (*Colocasia esculenta* L. Schott) flour, *Journal of Food Engineering* 81 pp. 250–256.

Njintang Y.N., 2003. Studies on the production of taro (*Colocasia esculenta*) flour for use in the preparation of achu-a taro base food. Ph.D thesis, University of Ngaoundéré, Cameroun.

Njintang, Y. N., Mbofung C. M. F. and Waldrom, K. W. 2001. In vitro protein digestibility and physicochemical properties of dry red bean flour (*Phaseolus vulgaris*) flour: Effect of processing and incorporation of soybean and cowpea flour. *J. Agric. Food Chem*, 49, 2465-2471.

O'Connor T.P. and O'Brien N.M., 1994. Lipid oxidation, in: Fox P.F. (Ed.), *Advanced Dairy Chemistry*-2: Lipids, Chapman and Hall, London, UK, pp. 309–347.

Stapelfeidt H., Nielsen B.R., Skibsted L.H., 1997. Effet of heat treatment, water activity and storage temperature on the oxidative stability of whole milk powder, *International. Dairy Journal*. 7. 331–339.