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Effect of Mild Treatments on Some Physicochemical and Pasting Characteristics of Flour from Two Cocoyam Cultivars

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Abstract. Effect of mild treatments namely; one-step annealing (AN), partial-nixtamalization (NIX) and phenolic-admixture (VAN) on some physicochemical and pasting characteristics of flour prepared using two cocoyam cultivars was studied. Both annealing treatment and phenolic admixture resulted in high peak viscosities (PV^{AN}_{white} = 322.50 RVU; PV^{VAN}_{white} = 306.67 RVU) of samples comparative to low peak viscosity ($PV^{control}_{white}$ = 227.25 RVU) of the control for white cultivar. Similarly, the peak viscosities (PV^{AN}_{red} = 310.70; PV^{VAN}_{red} = 296.45) of samples were higher than the peak viscosity ($PV^{red}_{control}$ = 225.42 RVU) of the control for red cultivar. Assessment revealed positive set back viscosities (SBV^{AN}_{red} = + 9.30 RVU; SBV^{AN}_{white} = + 21.33 RVU) for both the varieties after annealing treatment. Partial- NIX treatment showed molecular depolymerization. Interaction of treatments at levels employed in this study showed no synergistic effect. The pH of treated and control samples were within low acid range for foods. Mild treatment could be useful for tempering cocoyam flour for preparation of bakery and similar pasta products.

Keywords: cocoyam cultivars, flour, pasting characteristics

Introduction

Cocoyam, ranked after cassava and yam is the third largest root/tuber crop produced in Nigeria. The corms are characterised by high carbohydrate content. Its wide availability makes it a very good source of raw material for both the domestic and the industrial applications (Lawal, 2004). Although, efforts have been concerted on treatment of starch of cocoyam (Lawal, 2004) rather than the flour, the following reasons make it worth while to exploit flour rather than starch of cocoyam for modification. First, consideration of the proximate composition of cocoyam suggests that economics of purification, that is removal of non-carbohydrate components, principally fat and protein that may adversely affect rheological characteristics may not justify the effort applied, especially, when it forms the bulk of food as is the case of cocoyam. Secondly, non-starchy polysaccharides constitute major components of dietary fibre possessing high water absorption and form viscous mass which has desirable sensory attributes in foods. In addition, the cocoyam components could possess health benefits such as anti-diabetic, anti-tumogenic and anti-atherosclerosis effects (Subba Rao and Muralikrishna, 2002).

In the third place phenolic components of flour may exert therapeutic values. Further, most recent works delve on ennoblement of food products (pasta) using dietary fibres (Izydorczyk *et al*., 2005). More importantly, most food preparations are seldom pure, but a mixture of food components. Hence, refining of cocoyam flour may not be warranted if end product shall be a mixture of food components as applicable in preparations such as fries, flakes, puddies etc.

There are many methods of modifying starch, the principal component of cocoyam flour (James and West, 1997). Acceptability of any of the processes is determined by the amount of health risk associated with handling of modification process and safety status of the prepared product. Three treatment methods namely; annealing (Adebowale and Lawal, 2002; Delcour *et al*., 2000), alkaline processing (Martin-Martinez *et al*., 2003; Jackson *et al*., 2001) and addition of phenolics (Beta and Corke, 2003) had been used for treatment of starch or cereal kernels.

In tandem with the assertion of James and West (1997), little modification can result in alteration of physicochemical and functional properties of starch or starchy food stuffs. In the present work selected treatments at mild level were applied to red and white cocoyam cultivar flour and findings on the effect on its pasting and some physicochemical characteristics are reported here.

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Materials and Methods

White and red cocoyam varieties were procured from commercial centre. Vanillin (phenolic compound) and lime (calcium hydroxide) used were of analytical grade. Besides the dietary phenolic attributes, vanillin functions as anti-initiating agent in dietary chemo-preventive effects (Stoner *et al*., 2004).

Sample preparation. The corms were subjected to washing and the periderm was peeled off manually using knife. Each cultivar was then sliced-flaked using knife (average thickness = 1 mm) and treated prior to drying (T = 50 °C) using air-oven. Untreated lot was also dried and designated control sample.

Treatments. Annealing was accomplished using one step procedure: cocoyam wet flakes were heated (3.3% below gelatinization temperature of cocoyam starch) in water-suspension (1:2 w/w) for 1 h. The procedure (Delcour *et al*., 2000) was modified as necessary. Partial nixtamalization was accomplished by addition of lime solution (11.30 mM) to make flake suspension (1:2 w/w); held for 30 min, drained and rinsed with distilled water and dried (50 °C). Each of the treatments was either carried out separately or as combination as reflected in the Tables of results. Preparations (treated and control) were dried in air oven (T = 50 °C), milled, sieved and packaged for subsequent analysis.

Determination of pasting properties. Pasting properties of cocoyam flour, treated and control samples were characterized using rapid visco analyzer (RVA) as described by Delcour *et al*. (2000).

Five grammes of accurately weighed flour sample were added to water in the ratio of 1:2 (w/v). The sample slurry was heated from 28 °C to 150 °C at 4 °C/min and all experiments were carried out in triplicate. The RVA-3d was operated with 250 g of 9.9% starch-in-water suspension. The temperature profile included a 2 min isothermal step at 50 °C; linear temperature increase to 95 °C in 7 min, a holding step (8 min at 95 °C), a cooling step (7 min) with a linear temperature decrease to 50 °C and a final isothermal step at 50 °C. Measurements agreed within 5 RVU over the whole profile. Pasting peaks and associated parameters of paramount importance were identified and determined for technological interpretation.

Moisture content determination. Moisture content of cocoyam flour samples was determined in accordance with the method of AOAC (1990).

Measurement of pH. pH of the treated cocoyam flour and control samples were determined using Omega H.HPX digital meter. Standardization of the meter was carried out using the buffer solutions of pH 9 and 4. A 5 g sample was dispersed in 25 mL of distilled water. The mixture was stirred until an equilibrium pH was obtained and then pH was measured.

Determination of calcium content. Calcium content was evaluated using the method of AOAC (1990). Samples were analysed using Alpha-4-(Chemtech analytical) atomic absorption spectrophotometer.

Paste clarity determination. This was determined from percent light transmittance (%T) of cocoyam flour paste as described by Craig *et al*. (1989).

Determination of total phenolic content. Total phenolic contents were evaluated according to the method described by Taga *et al*. (1984) with little modification. Briefly, 100 µL of Folin-Ciocalteau reagent (2N wrt. acid Fluka Chemic AG-Ch 9470 BUCHS) was added to each flour sample (20 µL) and well mixed after addition of 1.58 mL of water to form slurry. After 30 sec, 300 µL of 20% sodium carbonate solution was added and the sample tubes were left at room temperature for 2 h and filtered. The filtrate was kept for the blue colour to develop and the absorbance (A) was measured at 750 nm using Unicam Helios & UV/VIS/Spectro-photometer. A plot of A_{750nm} against corresponding concentration was used to calculate total phenolic content (g ascorbic acid equivalent).

Determination of relative reducing power (RRP). The determination of RRP of the flour samples was accomplished using the method of Oyaizu (1986) with little modification slurry was formed of flour sample (1 mg/mL) in methanol (2.5 mL), mixed with 2.5 mL of 200 mM sodium phosphate buffer (pH 6.6, Wako Pure Chemical Co. Osaka, Japan) and 2.5 mL of 1% potassium ferric cyanide (Sigma). The mixture was incubated at 50 °C for 20 min. Afterwards, 2.5 mL of 10% trichloroacetic acid (w/v, Wako) was added and the mixture was centrifuged at 650 rpm for 10 min. The upper layer (5 mL) was mixed with 5 mL of deionized water and 1 mL of 0.1% ferric chloride (Wako) and the absorbance (A) was measured at 700 nm. A plot of A_{700nm} against corresponding concentration was used to calculate the RRP (mg ascorbic acid equivalent).

Determination of oil-binding capacity. Oil binding capacity was determined as follows: 5 mL of 10%

solution (0.5 g) of flour and 1 mL of refined corn oil in a graduated centrifuge tube (16.5 x 105 mm) were vigorously mixed using mixer. The mixture was then centrifuged at 600 x g for 20 min at room temperature (28 ± 0.5 °C). The volume of oil remaining above the slurry was directly read from the tube and subtracted from the initial volume of the oil added. Oil-binding capacity of the flour samples was expressed as mL of oil bound/g of flour sample. This was essentially done in accordance with the method of Seguchi (1984).

Determination of swelling capacity. Swelling capacity was determined in accordance with the method described by Leach *et al*. (1959) with modification for small samples at three temperature regime (60 °C, 70 °C and 80 °C).

Results and Discussion

Pasting characteristics. Anderson *et al*. (1994) reported that carbohydrate content especially starch is the most important factor that influences cooked potato texture. In addition, textural changes in potatoes and potato products occurring during thermal processing and cooking are mainly associated with the gelatinization and retrogradation behaviour of starch which represents the dominant component in potato roots/tubers (Alvarez *et al*., 2001). These assertions are peculiarity of all tuber crops because they essentially contain carbohydrates, although in different amounts. Hence rapid visco analyzer was used for assessment of cooking properties of the cocoyam flour samples.

Peaks/troughs of technological importance, as identified and extrapolated by RVA are shown in Table 1. The treatments caused increase in peak viscosity (PV) of the samples irrespective of the cultivar used. This observation is in agreement with some earlier reports; Adebowale and Lawal (2002) and Delcour *et al*. (2000) used annealing to treat starch and Beta and Corke (2003) studied effect of two phenolic compounds on sorghum and maize starches because, starch and other carbohydrates are the dominant components in cocoyam flour. PV indicates maximum water holding capacity of starch/starchy food substrate irrespective of the applied temperatures. Increase in viscosity could be mainly due to swollen granules and amount of soluble carbohydrates or susceptible macromolecules in the cocoyam flour. However, NIX-white and AN-NIX-white samples yielded opposite results. Different results obtained for the samples (NIX-white and AN-NIX-white) could be due to severity of the treatment which probably excessively depolymerised macromolecules leading to low viscosity in comparison to the other treated samples. Considering the effect of treatment on the pasting characteristic of the flour, it is prognosticated that one step annealing and phenolic admixture degrades/unfolds the secondary or tertiary structure of the cocoyam flour macromolecules, while partial-nixtamalization degrades/unfolds the primary structure

Table 1. Pasting characteristics of mild treated and control flour samples of red and white cocoyam cultivars

Sample	Peak visc (PV)	Trough (TR)	Breakdown visc (BDV)	Final visc (FV)	SV_1 (FV - TR)	Peak time (min)	Pasting temp (°C)	SV_2 (FN - PV)
Control-white	227.25	148.92	78.33	238.8	+89.17	4.82	64.00	+10.83
VAN-white	306.67	194.50	112.17	291.67	+97.17	4.24	63.80	-15.00
AN-white	322.50	220.08	102.42	343.83	+123.75	4.69	63.75	+21.33
NIX-white	219.50	138.50	81.00	194.92	+56.42	4,40	63.60	-24.58
VAN-NIX-white	269.33	170.75	98.58	256.42	+85.67	4.11	63.30	-12.91
VAN-AN-white	275.92	187.08	88.83	273.75	+86.67	4.33	64.20	-2.17
AN-NIX-white	178.17	117.92	60.25	177.25	+59.33	4.37	64.00	-0.92
VAN-AN-NIX-white	267.17	172.08	95.08	265.25	+93.17	4.07	63.35	-1.92
Control-red	223.42	144.47	78.75	218.92	+74.25	4.46	63.10	-4.50
VAN-red	291.45	180.24	100.63	290.60	+119.36	4.03	63.60	-0.85
AN-red	310.70	200.50	107.54	320.00	+119.50	4.05	63.50	+9.30
NIX-red	232.50	121.42	109.50	190.75	+69.33	3.94	63.80	-41.75
VAN-XIZ-red	243.17	148.33	94.83	215.08	+66.75	4.11	64.95	-28.09
VAN-AN-red	293.25	172.08	121.17	270.33	+98.25	4.07	63.55	-22.42
AN-NIX-red	256.50	149.58	106.92	214.67	+65.08	4.14	63.45	-41.83
VAN-AN-NIX-red	239.42	127.58	111.83	177.25	+49.67	4.11	63.45	-62.17

VAN = vanillin; AN = annealing; NIX = partial nixtamalization.

of the flour macromolecules, consequently, resulting in depolymerization of macromolecules. In addition, peak viscosity of all the NIX-treated samples (although higher than the control) were less than that of other treated samples.

All white cultivar treated samples showed higher trough viscosity with respect to control sample. However, all the samples showed variable breakdown viscosities (BDV) with majority higher than BDV of the control samples (white and red). This suggests that the additives never engaged in cross-linkage with cocoyam polymers/molecules. The final viscosity (FV), an index of stability of cooked paste to mechanical treatment of the samples is also presented in Table 1. All the samples were characterized with high FV comparative to the control samples. Some exceptions to the observation were NIX-white, AN-NIX-white, NIX-red, AN-NIX-red and VAN-AN-NIX-red samples. It appears as if the interactive consequence of heat and alkaline characteristic or the latter alone resulted in lowering FV. This observation also attests to the hypothesis that alkaline medium most probably caused degradation of primary structure of polymolecules in the cocoyam flour.

Setback viscosity. Set back viscosity (SBV) from the trough (SV_{-1}) was evaluated using the difference between the trough viscosity (TV) and final viscosity (FV), and set back viscosity from the peak (SV_{-2}) was evaluated as difference between the peak viscosity and the final viscosity. Though, treatment had less impact on SV_{-1}, but had significant impact on SV_{-2} with AN-white (SV_{-2} = + 21.33 RVU) and AN-red (SV_{-2} = + 9.30 RVU) samples characterized by the highest positive SBV. Positive set back viscosity reflects stability of the paste against retrogradation (Mazurs *et al.*, 1957). All the samples were characterized by lower cooking peak time. This suggests that treatment weakened the granules of the macro molecules of the samples thereby leading to less cooking time. Similarly, the pasting temperatures of the samples appear lower than the pasting temperature of the control samples.

The results clearly demonstrate that annealing modified cocoyam flours. This is similar to an earlier report by Dalbon *et al*. (1985) who stated that carbohydrate properties especially starch properties can be changed by a heat-moisture treatment. The treatment plays important role in pasting quality. Thus, the process could be exploited to temper cocoyam flour which may be useful for preparation of carbohydrate/starchy food stuff for production of pasta such as macaroni, spaghetti and other bakery products like biscuits, pizza etc.

Physicochemical characteristics. The assessment of the physicochemical properties is presented in Table 2.

Moisture content. Moisture content of the treated and control cocoyam flour samples were similar. This is because the samples were dried under the same drying conditions, thus giving rise to the same amounts of total solids in the analysed samples.

pH. pH of the samples ranged from 5.76 to 6.58, 5.80 to 6.45 for both treated and control flour samples of

Table 2. Selected physicochemical properties of mild treated and control flour samples of red and white cocoyam cultivars (average values)

Sample	Moisture content (%)	pH	Calcium (mg/100 g)	T (%)	Total* phenolic content	RRP**	Oil binding capacity (mL/g)
Control-white	8.60	6.35	7.02	19.73	2.364	N.D	1.472
VAN-white	8.45	6.29	6.05	48.98	1.909	N.D	1.355
AN-white	8.00	6.55	7.58	40.28	2.773	N.D	1.472
NIX-white	8.45	6.58	4.59	44.16	2.318	2.349	1.362
VAN-NIX-white	9.05	6.05	5.66	48.42	2.182	N.D	1.300
VAN-AN-white	8.40	5.76	4.18	23.45	1.364	N.D	1.349
AN-NIX-white	8.42	6.20	6.12	19.50	1.455	N.D	1.332
VAN-AN-NIX-white	8.00	6.44	4.78	37.17	2.546	N.D	1.216
Control-red	8.60	5.96	6.22	05.08	2.227	2.349	1.349
VAN-red	8.50	5.80	5.42	26.00	2.591	N.D	1.341
AN-red	9.00	6.20	6.50	35.90	2.955	2.349	1.341
NIX-red	9.05	6.45	3.77	14.29	2.682	18.793	1.419
VAN-XIZ-red	8.40	5.97	6.15	14.52	2.182	N.D	1.458
VAN-AN-red	8.70	6.18	5.28	28.51	2.682	N.D	1.405
AN-NIX-red	8.40	5.82	6.32	23.72	2.455	7.047	1.483
VAN-AN-NIX-red	8.45	6.22	6.33	24.85	3.500	16.402	1.474

* = g ascorbic acid equivalent/100 mL of slurry filtrate; **RRP = relative reducing power (mg ascorbic acid equivalent/100 mL of filtrate).

white and red cultivars, respectively. Considering the profile, the pH lies within low acid range for foods. But a closer examination of the profile of the white cocoyam cultivar shows that addition of vanillin (a phenolic compound) resulted in reduction of pH of the flour samples whereas nixtamalized samples showed increase in the pH. The result is plausible because of the alkaline treatment offerred by nixtamalization process. Similar trend was observed for flour of the red-cultivar. pH (5.96) of the control sample of red-cultivar is lower than the pH (6.35) of the control sample of white-cultivar. Lower pH of the red cultivar was probably due to its higher phenolic content which could probably be in acidic form.

Calcium content. Calcium contents of the control and the treated samples were not significantly different from one other. This connotes that modification was not due to calcification but probably due to solvation energy released by the lime solution.

Transmittance. Transmittance (T %) of the samples indicated that treatment improved the transmittance (%) or decreased the translucency of the paste in comparison to the control samples. In addition, it also suggested that the treatment resulted in degradation of macro-molecules in the samples. This is in agreement with the assertion of Lawal (2004) concerning cocoyam white variety starch, that reduction of interchain association facilitated improvement of the transmittance. Generally, white cocoyam cultivar flour samples were characterized by high transmittance comparative to the low one of red cultivar. The latter could be partly due to the interference of brownish phenolics/resins present or it could mean that the red cultivar has carbohydrate components with firmer structural integrity. Among the treated white cultivar flour samples, VAN-white and VAN-NIX-white, had the highest transmittance 48.98% and 44.16%, respectively. From the evaluation, treatment did not show synergistic effect on paste translucency. The highest (36.31%) transmittance in red cultivar sample is associated with AN-red sample.

Total phenolic content (TP). Quantitative analysis showed that TP (g ascorbic acid equivalent/100 mL of filtrate) ranged from 1.909 to 3.500. The TP of the untreated samples were 2.364 and 2.227 for white and red cocoyam cultivars, respectively. Treatments lend more loss of TP in white samples in comparison to the red ones.

Relative reducing power (RRP). Reducing power is one of the indices of health maintenance potential of food. In the present study, RRP (mg ascorbic acid equivalent/100 mL filtrate), was not detected in almost all white cocoyam samples. However, this does not imply the lack of reducing power, but the observation could be the result of non-solubility of reductones because test was conducted using the filtrate. The highest values, 18.79 and 16.40, were observed for NIX-red and AN-VAN-NIX-red samples, respectively. This result suggests that the red cultivar has better reducing power comparative to the white cocoyam cultivar.

Oil binding capacity. Oil binding capacity (mL/g) of the treated and the control samples ranged from 1.341-1.474 and 1.216, to 1472 for the red and the white cultivars, respectively. Considering the result, it appears that the treatment conferred no tangible difference on the samples. Nevertheless, treatments improved the oil binding capacity of AN-NIX-red and VAN-AN-white samples.

Swelling capacity. Swelling capacity, a measure of hydration capacity, was evaluated as weight of swollen flour granules and occluded water. Swelling capacity determined at the temperatures 40,50,60 and 70 °C is shown in Table 3. Generally, treatments enhanced swelling capacity of samples comparative to the control (untreated) sample. According to Whistler and Daniel (1985), the phenomenon entails treatment that breaks or at least weakens intermolecular bonds thereby allowing hydrogen bonding site to engage more water

Table 3. Swelling capacity (g/g) of mild treated and control flour samples of red and white cocoyam cultivars (average values)

Sample	Temperature (°C)			
	40	50	60	70
Control-white	1.238	3.337	4.212	4.248
VAN-white	1.229	3.933	3.900	4.202
AN-white	2.603	3.314	3.924	4.144
NIX-white	1.937	3.511	3.940	4.109
VAN-NIX-white	1.530	3.542	4.131	4.728
VAN-AN-white	1.227	2.935	4.038	4.520
AN-NIX-white	1.237	3.123	4.521	4.547
VAN-AN-NIX-white	1.224	3.630	4.203	4.413
Control-red	0.643	2.628	3.600	4.200
VAN-red	1.436	2.820	3.717	4.248
AN-red	1.221	3.708	3.745	4.313
NIX-red	1.203	2.812	3.906	4.144
VAN-NIX-red	1.130	4.223	3.91	4.218
VAN-AN-red	1.849	3.142	3.937	4.833
AN-NIX-red	1.428	3.243	3.737	4.006
VAN-AN-NIX-red	2.029	2.845	4.136	4.527

molecules, leading to improved swelling capacity. Examination of the results revealed that treatments in which heat (annealing) and/or VAN were applied synergistically reacted with NIX- treatment resulting in improvement of swelling capacity. The food eating quality is often connected with the retention of water in the swollen starch/carbohydrate granules (Richard *et al*., 1992). Differences in the swelling capacity of the samples (treatment) indicate the extent of impact of the treatment on the strength of associative bonding force within the granules. The treatment probably caused weakening of bonding within the crystalline domain of granules (Makkar *et al*., 1997), leading to improved swelling capacity.

Conclusion

Assessment of the effect of mild treatments, namely one-step annealing, alkaline and phenolic admixtures, on the selected pasting and physicochemical properties of flours of red and white cocoyam cultivars showed that annealing and phenolic admixture resulted in improvement of peak viscosity, while partial-nixtamalization resulted in reduction of viscosity. Non-alteration of pH of preparations for the range of low acid foods supports the premise of mild treatment. Such tempered flour can be used as base ingredient in preparation of specific food commodities such as pasta/bakery products like cake, noodles, flakes and puddies.

References

Adebowale, K.O., Lawal, O.S. 2002. Effect of annealing and heat moisture conditioning on the physicochemical characteristics of bambarra groundnut (*Voandzeia subterranean)* starch. *Food/Nahrung*, **46:** 311-316.

Alvarez, M.D., Canet, W., Tortosa, M.E. 2001. Kinetics of thermal softening of potato tissue (*cv. Monalisa)* by water heating. *European Food Research and Technology*, **212:** 588-596.

Anderson, A., Gekas, V., Lind, I., Oliverira, F., Oste, R. 1994. Effect of pre-heating on potato texture. *Critical Review in Food Science and Nutrition*, **34:** 229-251.

A.O.A.C. 1990. *Official Methods of Analysis*, Association of Official Analytical Chemists, 13th edition, Washington, DC., USA.

Beta, T., Corke, H. 2003. Effect of ferulic acid and catechin on sorghum and maize starch pasting properties. *Cereal Chemistry*, **81:** 418-422.

Craig, S.A.S., Maningat, C.C., Seib, P.A., Hosenet, R.C. 1989 Starch paste clarity. *Cereal Chemistry*, **66:** 173-182.

Dalbon, G., Pagani, M., Resmini, P., Lucisano, M. 1985. Einflusseeiner hitzebehandlung der weizenstarke wahrend des trocknungsprozesses (Impact of wheat starch thermal treatment during the pasta drying process). *Getreide, Mehl Und Brot*, **39:** 183-189.

Delcour, J.A., Vansteeland, J., Hythier, M.C., Abecassis, J. 2000. Fractionation and reconstitution experiments provide insight into the role of starch gelatinization and pasting properties in pasta quality. *Journal of Agricultural and Food Chemistry*, **48:** 3774-3778.

Izydorczyk, M.S., Lagasse, S.L., Hatcher, D.W., Dexter, J.E., Rossnagel, B.G. 2005. The enrichment of Asian noodles with fiber-rich fractions derived from roller milling of hull-less barley. *Journal of the Science of Food and Agriculture*, **85:** 2094-2104.

James, N.B., West, L. 1997. Starch modification challenges and prospects. *Starch/Starke*, **2:** 127-131.

Jackson, D.S., Sahai, D., Mua, J.P., Surjewan, I., Buendia, M.O., Rowe, M. 2001. Alkaline processing (Nixtamalization) of white Mexican corn hybrids for tortilla production: significance of corn physicochemical characteristics and process conditions. *Cereal Chemistry*, **2:** 116-120.

Lawal, O.S. 2004. Composition, physicochemical properties and retrogradation characteristics of native, oxidized, acetylated and acid-thinned new cocoyam *(Xanthosoma sagittitolium)* starch. *Food Chemical*, **87:** 205-218.

Leach, H.W., McCowen, L.D., Schoch, T.J. 1959. Structure of the starch granules. Swelling and Solubility Patterns of Various Starches. *Cereal Chemistry*, **36:** 534-544.

Makkar, H.P.S., Becker, K., Abel, H., Pawelzik, E. 1997. Nutrient contents, rumen protein degradability and antinutritional factors in some colour and white flowering cultivars of *Vicia faba* beans. *The Journal of the Science of Food and Agriculture*, **75:** 511-520.

Martin-Martinez, E.S., Jaime-Fonseca, M.R., Matinez-Bustons, F., Martinez montes, J.L. 2003. Selective nixtamalization of fractions of maize grain (*Zea mays* L.) and their use in the preparation of instant tortilla flours analyzed using response surface methodology. *Cereal Chemistry*, **1:** 13-19.

Mazurs, E.G., Schoch, T.J., Kite, F.E. 1957. Graphical analysis of the brabender viscosity curves of various starches. *Cereal Chemistry*, **3:** 141-153.

Oyaizu, M. 1986. Studies on extracts of browning reaction: antioxidative activities of extracts of browning reactions prepared from glucosamine. *Japanese Journal of Nutrition*, **44:** 307-315.

Richard, J.E., Blanshard, J.M.V., Asaoka, M. 1992. Effect of cultivar and growth season on the gelatinization properties of cassava *(Manihot esculenta)* starch. *Journal of the Science of Food and Agriculture*, **59:** 53-58.

Seguchi, M. 1984. Oil-binding capacity of prime starch from chlorinated wheat flour. *Cereal Chemistry*, **3:** 241-244.

Stoner, G.D., Morse, M.A., Wogan, G.N. 2004. Foods and food components in the prevention of cancer. In: *Bioprocesses and Biotechnology for Functional Foods and Nutraceuticals*, pp. 331-375, J. R. Nesser and J. B. German, (eds.), Marcel Dekker, New York, USA.

Subba Rao, M.V.S.S.T., Muralikrishna, G. 2002. Evaluation of the antioxidant properties of free and bound phenolic acids from native and malted finger millet (Ragi, *Eleusine coracana* Indaf-15). *Journal of Agricultural and Food Chemistry*, **50:** 889-892.

Taga, M.S., Miller, E.E.E., Pratt., D.E. 1984. Chia seeds as a source of natural lipid antioxidants. *Journal of American Oil Chemical Society*, **61:** 928-932.

Whistler, R.L., Daniel, J.R. 1985. Carbohydrates. In: *Food Chemistry*, pp. 69-138, 2nd edition, O.R. Fennema (ed.), Marcel Dekker, New York, USA.