Physicochemical Properties and Pasting Behaviours of Selected Tropical Tubers

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ABSTRACT

Proximate compositions, physicochemical properties and minerals of starches extracted from the corms and cormels of white cocoyam (Colocasia esculenta), corms of red cocoyam (Colocasia esculenta) and bitter yam (Dioscorea dumetorum) were determined using standard methods. The ranges of proximate compositions (%) in terms of crude protein, ash, fat, crude fibre, carbohydrates by difference and moisture contents were 1.17±0.01-2.09±0.01, 1.72±0.02-1.88±0.02, 0.33±0.01-0.52±0.01, 0.46±0.01-0.69±0.02, 85.61±0.05-86.03±0.19 and 9.36±0.02-10.10±0.10 respectively. The studies showed that the increasing order of bulk densities of the samples was red cocoyam corms<white cocoyam corms<white cocoyam cormels=bitter yam. Starches of the corms of both cultivars exhibited higher values of water absorption capacity than the starch of white cocoyam cormels. The highest value of least gelation concentration, 15.00±0.02% was significantly similar ($p<0.05$) for the starches of white cocoyam cormels and bitter yam. The values of amylose (%), swelling power (g/g) and solubility (%) ranged between 16.50±0.01 and 25.15±0.01, 8.03±0.01-11.21±0.01 and 7.35±0.01-8.44±0.01 respectively. Bitter yam starch was most viscous (329.50 RVU) with peak stability (181.83 RVU) at 61.95^{0}C in 5.18 mins.

INTRODUCTION

Roots and tubers are plants that store edible material in subterranean roots, corms or tubers[1], mainly consisting of starch, which is the only qualitatively important digestible polysaccharides being regarded a nutritionally superior to low molecular carbohydrate or sugars[2]. Starch occurs widely in nature and is the most commonly used[3], owing partly to its various native and modified forms, and partly to its low relative cost[3]. Starch is an important ingredient in food and non-food industries (such as paper, plastic, adhesive, textile and pharmaceutical industries).

Colocasia esculenta is an ancient tuber of the Araceae family, existing as both red and white cultivars[4,5] whose starch granules are smaller than those of potato in the ratio[6] 1:10.

Wild forms of D. dumetorum do contain bitter principles, and hence are referred to as bitter yam. Bitter yams are not normally eaten except at times of food scarcity. They are usually detoxified by soaking in a vessel of salt water, in cold or hot fresh water or in a stream. The bitter principle has been identified as the alkaloid dihydrodioscorine while that of the Malayan species, *D. hispida*, is dioscorine[7].

In our earlier study, we have studied the physicochemical properties and pasting behaviours of starches of cormels of red cocoyam (*Colocasia esculenta*) and sweet potato (*Ipomea batata*), revealing that the starch of sweet potato has higher priority standing as alternative binder and disintegrants in tablet formulation than the starch of red cocoyam cormels owing to their appreciably high values of swelling power, bulk density and viscosity[8].

This paper focuses on the possible industrial applications of starches extracted from corms and cormels of white cocoyam, corms of red cocoyam and bitter yam with the view to comparing with the starches of red cocoyam cormels and sweet potato whose physicochemical properties and pasting behaviours have earlier been reported.

EXPERIMENTALS

Corms and cormels of white cocoyam (*Colocasia esculenta*), corms of red cocoyam (*Colocasia esculenta*) and tubers of bitter yam (*Dioscorea dumetorum*) were purchased at Oja-Oba market, Akure, Nigeria. The starches of the tubers were extracted by first washing with water, peeling, slicing, rewashing and grating to obtain the pulp, which was sieved through muslin bag. The filtrate (starch milk) was allowed to stand for sometime for the starch to settle before decanting the supernatant to obtain wet starch cake. The wet starch cakes of the samples were sun dried, ground into fine powder, packaged into transparent polyethylene bags and labelled prior to analysis.

The crude protein, crude fibre, moisture and ash contents of the starch samples were determined using the method of AOAC[9]. The method described by Pearson et. al.[10] was used for fat content analysis. Carbohydrate was obtained by difference 100% - (moisture + protein + fat + ash + fibre) %. The method described by Wang and Kinsella[11] was used for bulk density determination. The water absorption capacity was determined as reported by Akintayo[12] while least gelation concentration was evaluated using the method reported by Coffman and Garcia[13]. The method reported by Song and Jane[14] was used for amylose and amylopectin contents analysis. The solubility and swelling power were carried out using the methods described by Leach et. al. [15]. A Rapid Visco-Analyzer (Model: 3-D, Newport Scientific, Australia, 1995) with Thermocline for windows software was used to evaluate of the pasting properties of the starch samples. Viscogram profile/pasting curves show the relationship between time, viscosity and temperature during cooking processes. Test runs were conducted following standard profile 1 which included 1 min of mixing, stirring, and warming up to 50^0C, 3 min and 42 sec of heating at 12^0C /min up to 95^0C, 2.5 min of holding at 95^0C, 3 min and 48 sec of cooling down to 50^0C, at the same rate as the heating (12^0C/min) and 2 min holding at 50^0C, where the process ended after 13 minutes[16] (Deffenbaugh and Walker, 1989). Starch gelatinization (pasting) curves were recorded on RVA and viscosity was expressed in terms of Rapid Visco Units (RVU) which is equivalent to 10 centipoises.

RESULTS AND DISCUSSION

The proximate compositions of the starch samples are presented in Table 1. Percentage crude protein of the starch samples range from 1.17±0.01 (cormels of white cocoyam) to 2.09±0.01 (corms of red cocoyam) with those of bitter yam and corms of white cocoyam significantly similar ($p<0.05$). Starch of corms of red cocoyam depicts higher value of crude protein than those of sweet potato (1.63±0.01%) and cormels of red cocoyam (1.41±0.01%) reported by Oladebeye et. al. [8].

Table 1: Proximate Compositions of the Starch Samples

Starch Sample	Moisture Content (%)	Crude Fibre (%)	Ash Content (%)	Fat Content (%)	Crude Fibre (%)	Carbohydrates by Difference (%)
White Cocoyam Corms	$9.36^{b}\pm0.02$	$1.87^{b}\pm0.01$	$1.88^{d}\pm0.02$	$0.52^{d}\pm0.01$	$0.46^{a}\pm0.01$	$85.91^{b}\pm0.03$
White Cocoyam Cormels	$10.10^{d}\pm0.10$	$1.17^{a}\pm0.01$	$1.82^{c}\pm0.01$	$0.43^{c}\pm0.01$	$0.50^{b}\pm0.01$	$85.98^{b}\pm0.01$
Red Cocoyam Corms	$9.59^{c}\pm0.04$	$2.09^{c}\pm0.01$	$1.72^{a}\pm0.02$	$0.41^{b}\pm0.01$	$0.58^{c}\pm0.01$	$85.61^{a}\pm0.05$
Bitter Yam	$9.33^{a}\pm0.07$	$1.87^{b}\pm0.01$	$1.75^{b}\pm0.02$	$0.33^{a}\pm0.01$	$0.69^{d}\pm0.02$	$86.03^{c}\pm0.19$

Results are the means of triplicate determinations ± standard deviation. Means with different superscripts in the same column are significantly different ($p<0.05$.

Table 2: Physicochemical Properties of the Starch Samples

Starch Sample	Bulk Density (g/ml)	Water Absorption Capacity (%)	Least Gelation Concentration (%)	Amylose Content (%)	Amylo-pectin Content (%)	Swelling Power (%)	Solubility (%)
White Cocoyam Corms	$0.72^{a}\pm0.01$	$92.74^{d}\pm0.03$	$10.00^{a}\pm0.01$	$19.21^{b}\pm0.05$	$80.79^{c}\pm0.04$	$9.86^{c}\pm0.02$	$8.44^{c}\pm0.01$
White Cocoyam Cormels	$0.75^{b}\pm0.01$	$88.23^{c}\pm0.01$	$15.00^{b}\pm0.01$	$25.15^{d}\pm0.03$	$74.85^{a}\pm0.03$	$8.03^{a}\pm0.03$	$7.56^{b}\pm0.02$
Red Cocoyam Corms	$0.71^{a}\pm0.01$	$84.41^{b}\pm0.02$	$10.00^{a}\pm0.01$	$16.50^{a}\pm0.02$	$83.50^{d}\pm0.01$	$11.21^{d}\pm0.05$	$8.40^{c}\pm0.01$
Bitter Yam	$0.75^{b}\pm0.02$	$83.23^{a}\pm0.02$	$15.00^{b}\pm0.02$	$23.65^{c}\pm0.03$	$76.35^{b}\pm0.02$	$9.56^{b}\pm0.04$	$7.22^{a}\pm0.01$

Results are the means of triplicate determinations ± standard deviation. Means with different superscripts in the same column are significantly different ($p<0.05$)

The peak value of ash content (1.88±0.02) obtained for is higher than that reported for sweet potato (1.64±0.01%) and lower than 1.98±0.02% for cormels of red cocoyam by Oladebeye et. al. [8]. All the starch samples are very rich in carbohydrates with values varying from 85.61±0.05 to 86.03±0.19%. The least value of moisture content (9.33±0.07%) obtained in bitter yam starch suggests its highest stability against microbial activity.

Table 2 depicts selected physicochemical properties of the samples. The percentage bulk densities of the starch samples range from 0.71±0.01 to 0.75±0.01 with starches of white cocoyam cormels and bitter yam significantly similar ($p<0.05$) with the peak value.

Bulk density, as a function of suitability of starch as disintegrants and binder in tablet formulation, suggests starches of white cocoyam cormels and bitter yam as possible alternative binders and disintegrants. The values of water absorption capacity and least gelation concentration of the samples suggest a possible relationship between the two intrinsic functional properties. It appears that the granules of starch with high capacity to absorb water exhibit low tendency for formation of gel within the micelles. Amylose and amylopectin contents of the starch samples are significantly different ($p<0.05$). Thomas and Atwell[17] have reported differences in amylose and amylopectin contents as bases for significant differences in starch properties and functionality. Amylose has been reported as both diluent and inhibitor of swelling[18,19]. This may account for corresponding drop in swelling powers of the starch samples relative to their amylose contents.

From Table 3, bitter yam starch exhibits highest stability (181.83 RVU) coupled with highest paste viscosity (329.50 RVU) at 61.95^{0}C within 5.18 mins. The peak values of paste stability and viscosity obtained in bitter yam starch are, however, lower and higher than those reported by Oladebeye et. al [8] for sweet potato and cormels of red cocoyam starches respectively.

Retrogradation is an index of texture and acceptability of starch-containing products; it is responsible for staling of bread, a cake not risen well, cream separated, running pastes and glue due to low values of viscosity[20].

RVA pasting curves of the starch samples are shown in Figure 1 – 4.

Table 3: Pasting Properties of the Starch Samples

Starch Sample	Pasting Time (mins)	Gelatinization Temperature (^{0}C)	Paste Viscosity (RVU)	Retrogradation (RVU)	Stability (RVU)
White Cocoyam Corms	5.08	61.55	304.67	72.83	112.00
White Cocoyam Cormels	4.79	62.15	273.58	68.33	95.58
Red Cocoyam Corms	4.96	61.25	241.08	61.50	86.58
Bitter Yam	5.18	61.95	329.50	78.25	181.83

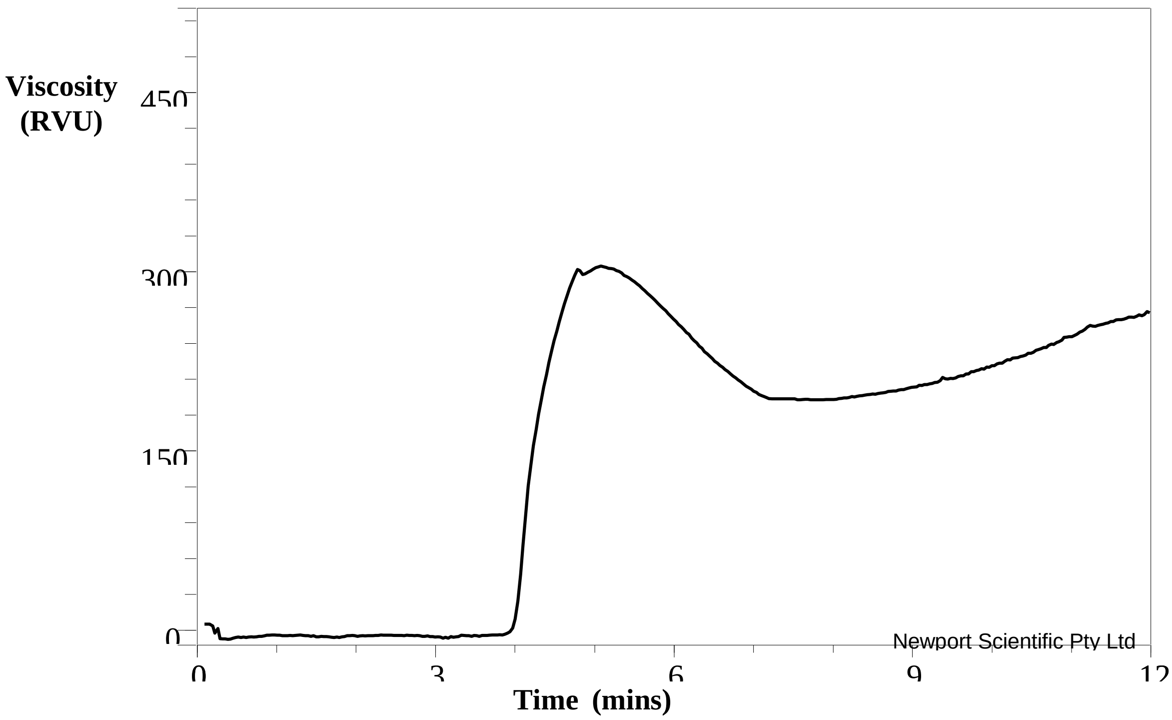

Figure 1: RVA Pasting Curve of Corms of White Cocoyam Starch

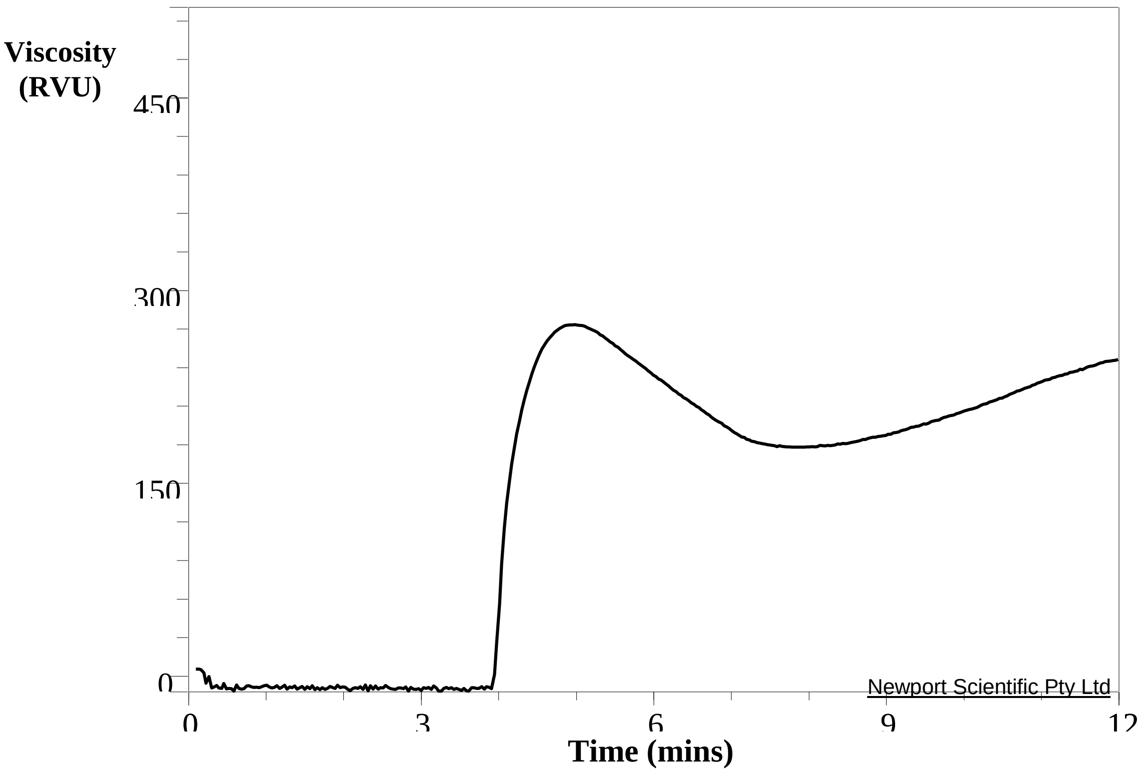

Figure 2: RVA Pasting Curve of Cormels of White Cocoyam Starch

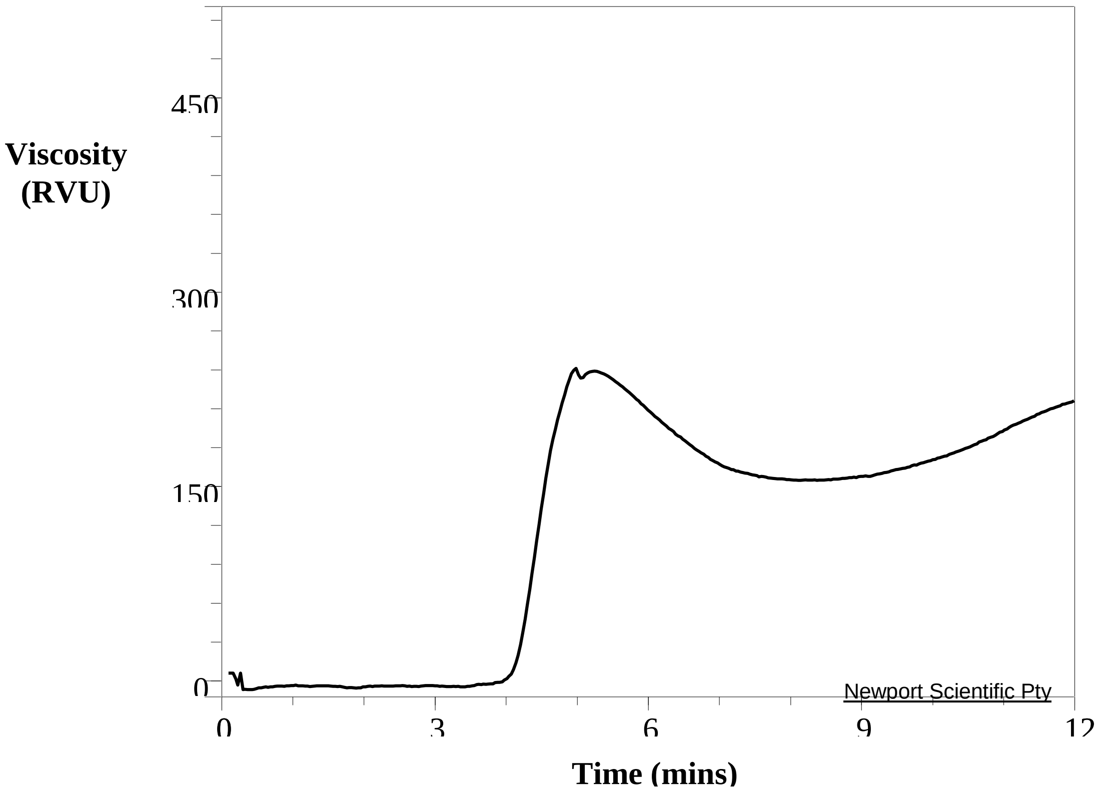

Figure 3: RVA Pasting Curve of Corms of Red Cocoyam Starch

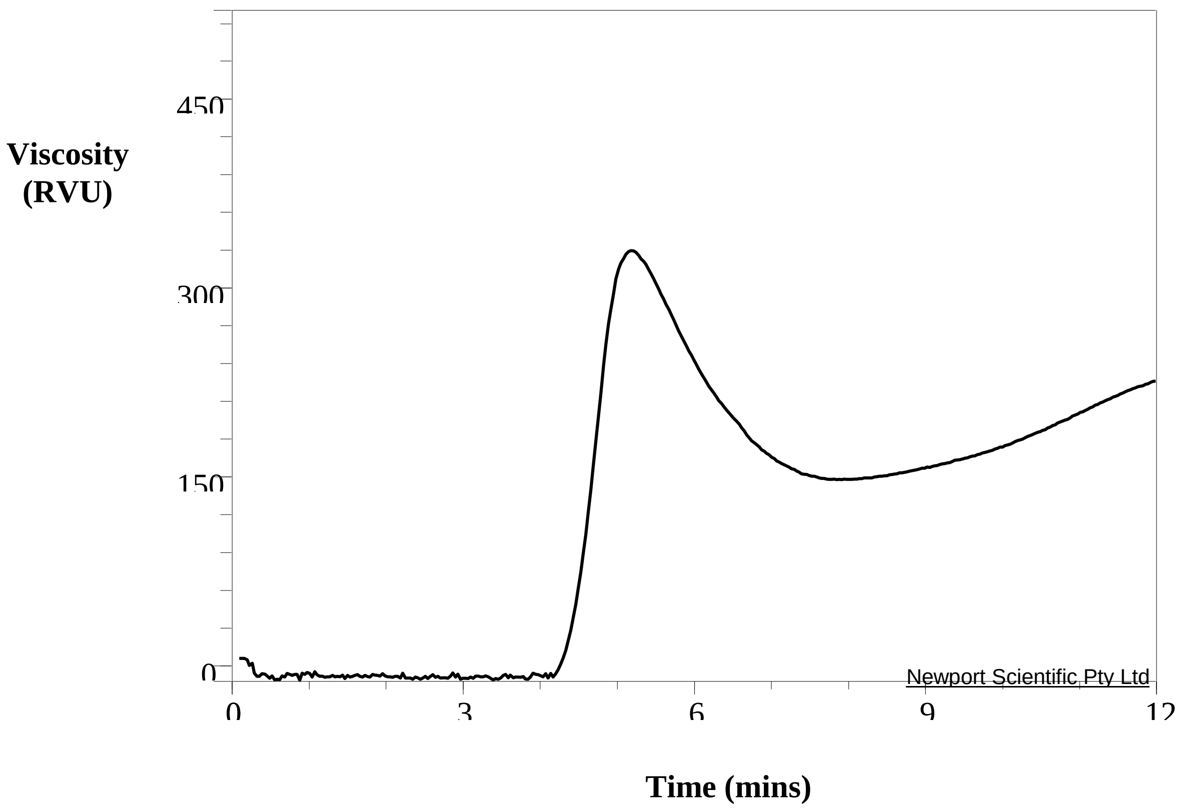

Figure 4: RVA Pasting Curve of Bitter Yam Starch

CONCLUSION

Starch of bitter yam stands the best chance of possible alternative drug binder and disintegrants in tablet formulation compared to the starches of corms and cormels of white cocoyam and corms of red cocoyam. In applications where viscosity is an index of characterization, all the starches studied may find applications owing to their appreciably high values of viscosity.

REFERENCES

1. Oke, O.L.; *West Af. J. Pharm.* 9 (1967):52

2. Malcolm, P.S. (1990). Polymer Chemistry: An Introduction, 2nd Edition, Oxford University Press, New York.

3. Whistler, R.L., BeMiller, J. and Paschall, E.F. (1984). Starch Chemistry and Technology, 2nd Edition, Academic Press, Inc., New York**.**

4. Ogbeide, O.; *American Journal of Clinical Nutrition* 27 (1974): 213

5. Ojofeitimi, O.E. and Tanimowo, C.M.; *Integrated Journal of Gynaecology and Obstetric* 18(1980): 66

6. Ojofeitimi, O.E. and Oke, O.L.**;** *World Rev. Nutr. Dietetics* 32 **(**1980): 133

7. Bevan, C.W.L. and Hirst, J.; *Chem. Ind.* 25, (1958): 103.

8. Oladebeye, A.O., Oshodi, A.A. and Oladebeye, A.A.; *Pakistan J. Nutri*. 8(4) (2009): 313-315.

9. AOAC, Association of Official Analytical Chemists (1990). Official Methods of Analysis of the Association of Official Analytical Chemists (18th edition), Washington D.C.

10. Pearson, D., Egan, H., Kirk, R.S. and Sawyer, R. (1981). Pearson's Chemical Analysis of Food, Churchill Livingston, Edinburgh

11. Wang, J.C. and Kinsella, J.F.; *J. Food Science*, 41(1976): 286-289.

12. Akintayo, E.T. 1999. Physicochemical Properties of Protein Concentrates and Starches of African Yambean (*Sphenostylis sternocarpa),* Lima Bean *(Phaseolus)* and Pigean Peas *(Cajanus cajan)*. PhD Thesis, pp. 67-72, The Federal university of Technology, Akure, Nigeria.

13. Coffman, C.W. and Garcia, W.; *J. Food Tech.* 12 (1977):473-484

14. Song, Y. and Jane, J.; *Carbohydr. Polymers* 41(2000):365-377

15. Leach, H.W., McCowen, L.D. and Schoch, T.J.; *Cereal Chemistry* 36 (1959):534-541.

16. Deffenbaugh, B.L. and Walker, E.C.; *Chemistry* 66 (1989): 493-499.

17. Thomas D.S. and Atwell, W.A. (1999). Starch Structure. In: Starches. Critical guides for the food industry, (Series Ed.), pp 1, 2, 25-30, Eagan Press Handbook series St. Paul, Minnesota, USA.

18. Tester, R.F. and Karkalas, J.; *Cereal Chem.* 78 (1996):271-273

19. Zeleznak, K.J. and Hoseney, R.C.; *Cereal Chem.* 64(1987): 121-124.

20. Alais, C., Liden, G., Morton, I. and Whitehead, A. (1999). Food Biochemistry. Aspen Publ., Inc., Gaithersburg.