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The physico-functional characteristics of starches from cowpea (*Vigna unguiculata*), pigeon pea (*Cajanus cajan*) and yambean (*Sphenostylis stenocarpa*)

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Abstract

Starches fractionated from cowpea (*Vigna unguiculata*, Ife Brown), pigeon pea (*Cajanus cajan*, Cita II) and yambean (*Sphenostylis stenocarpa*) were comparatively studied for physical and functional properties, including granule morphology, granule sizes, water absorption capacity, water–oil absorption index, swelling capacity, ionic property, bulk density and amylographic viscosities. The three legume starch granules range in diameter size from 5–57.5 μm. The water absorption capacities of all the starches were generally low at room temperature up to 70°C. Pigeon pea starch was the least susceptible to swelling while the cowpea starch was the most susceptible. The starches displayed non-ionic character, low water activity, high bulk density, water and oil absorption capacities and type C Brabender visco-amylograms at 6.2% starch-water slurry (on dry wt basis). © 1999 Elsevier Science Ltd. All rights reserved.

Keywords: Starch; Granules; Fissures; Non-ionic; Swelling; Viscosity

1. Introduction

Cowpea (*Vigna unguiculata*, Ife Brown), pigeon pea (*Cajanus cajan*, Cita II) and yambean (*Sphenostylis stenocarpa*) are pulses of the tropical and sub-tropical areas of the world. Of the three grain legumes, cowpea varieties are the most widely cultivated and utilized as food and research materials in most countries of the world. Although India accounts for 85% of the world supply of pigeon pea, this legume is becoming popular in several countries of Africa and South East Asia (ICRISAT, 1981). The African yambean is indigenous to parts of tropical Africa (Duke, Okigbo, & Reed, 1977; NAS, 1979).

Chemical analysis has revealed these legumes to be rich not only in crude protein but also in starch. The preferential use of the legumes as human food is predominantly based on their importance as a cheap source of protein. About 19–40% protein composition range has been reported for food legumes (Boulter & Derbyshire, 1978); starch, which constitutes about 45–65% of the composition of edible legumes, has been shown to be the major component of commercially important pulses (Longe, 1981; Norton, Bliss, & Bressani, 1985). Starches of cereals and tubers, identified with suitable physical and chemical properties, are used as thickeners, extenders, stabilizers, gelling agents, dietary calories, and texture modifiers in food formulations (Wurzburg, 1968). It has also been reported that legume starch pastes are comparatively more viscous than the cereal starches, indicating that they have higher resistance to swelling and rupture than the latter (Lineback & Ke, 1975). Fractionated legume starches may, therefore, be used as ingredients in various industrial applications as are cereal and tuber starches. This paper provides a discussion on the physico-functional properties of cowpea, pigeon pea and yambean starches.

2. Materials and methods

2.1. Fractionation of starch

Starch was extracted from non-defective legume grains in accordance with the fractionation scheme of Schoch and Maywald (1968), with some modifications. While the cowpea was soaked in 0.3% NaOH solution

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for only 2 h the yambean and pigeon pea seeds were similarly soaked overnight at a seed:liquid ratio of 1:4 w/w. The cowpea absorbed soaking solution and softened faster than either the yambean or pigeon pea. The softened grains were drained and wet-milled in a Waring blender at low speed with ice-cold 0.8% sodium hydroxide solution (in the case of pigeon pea and yambean) and 0.2% NaOH (in the case of cowpea). The yambean and pigeon pea proteins are more strongly bound to starch granules than is the cowpea protein. The application of alkali was to remove the protein as much as possible. The alkalies were applied cold so as to prevent gelatinization of the starch by the heat generated during wet milling. The slurried pastes were separately filtered through a nylon bolting cloth and a sieve of 106-μm mesh size. The starches were subjected to a fast tabling procedure using deep freezer cooling. Prior to final tabling, starch slurries were neutralized with a standard acid and washed several times with deionized water. The starches were finally purified with 50% ethanol, de-watered and sun-dried for a period of 3 days in wooden trays screened with fine nylon mesh.

2.2. Analytical methods

Ground starch samples were analysed for: ionic characteristics by staining with an acidic solution of methylene blue (Kahn, 1987); bulk density, using the method of Okezie and Bello (1988); water and oil absorption capcities (WAC and OAC, respectively) following the methods outlined by Quinn and Paton (1979) and Lin, Humbert, and Sosulski (1974) respectively, water–oil absorption index as estimated by De Kanterewicz, Elizalde, Pilosof, and Bartholomai (1987); swelling capacity as determined by Sathe, Iyer, and Salunkhe (1981), at 10°C intervals between 60 and 90°C; and measurement of diameter sizes of at least 400 granules with a calibrated ocular eyepiece and a haemocytometer chamber on a light microscope (Anderson, 1978). The photomicrographs of starch granules mounted in 50% glycerine–water mixture were taken using a Carl Zeiss WL microscope equipped with polarized light. The pasting characteristics of 6.2% starch (on dry wt basis) slurries in water were also measured with a Brabender visco-amylograph equipped with 6.85×10 dyne-cm torque operated at 75 rpm bowl speed.

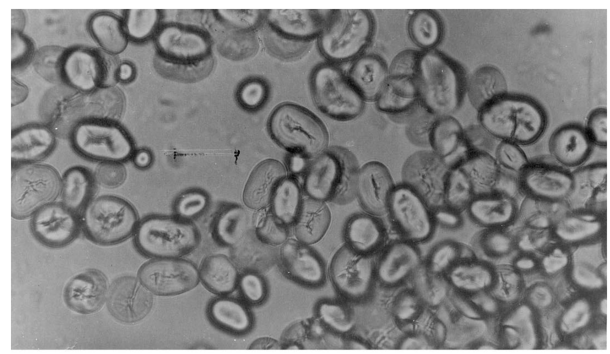
3. Results and discussion

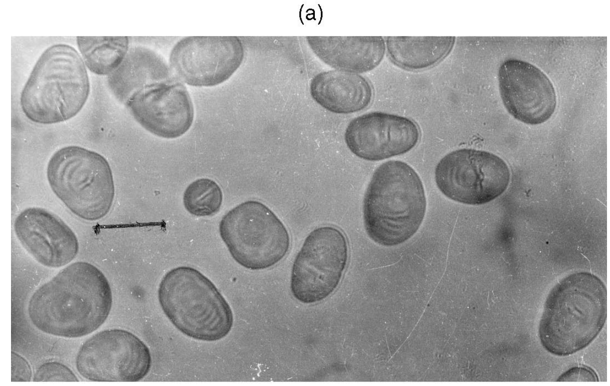
The physico-functional properties shown in Table 1 indicate that cowpea starch (CPS), pigeon pea starch (PPS) and yambean starch (YBS) were non-ionic, had high bulk density (1.01–1.08), and displayed low water activity (a_w) (0.62–0.65). Their WAC and OAC varied from 91.17–103.79 and 60.58–79.937, respectively. Their

Table 1
Some physical/functional properties of three legume starches

Parameter	Yambean starch	Cowpea starch	Pigeon pea starch
Ionic characters	Non-ionic	Non-ionic	Non-ionic
Bulk density (g/ml)	1.07 ± 0.02	1.08 ± 0.02	1.01 ± 0.02
Water activity (aw)	0.62 ± 0.01	0.63 ± 0.01	0.65 ± 0.01
Water absorption capacity (% dwb)	91.17 ± 2.3	94.40 ± 2.5	103.79 ± 4.4
Oil absorption capacity (% dwb)	60.58 ± 4.0	63.88 ± 3.2	79.93 ± 5.4
Water–oil absorption index	1.51	1.48	1.30

Mean values ± standard error of four determinations.


(a)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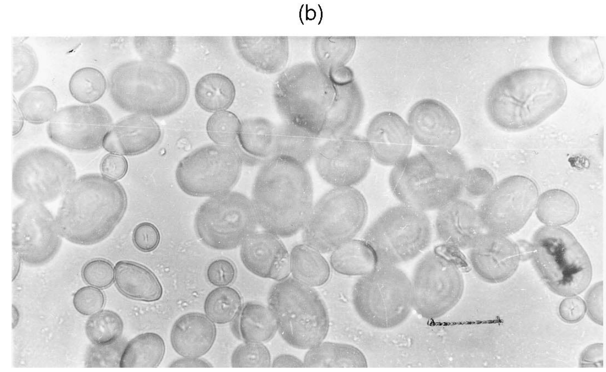
(c)

Plate 1. Photomicrographa of different starch granules. (a) Cowpea; (b) Pigeon pea; (c) Yambean.

water–oil absorption indices (WOAI) were generally low (1.30–1.51).

The common non-ionic characteristic of the legume starches conforms with the reports of Schoch and Maywald (1968) and Kahn (1987). This non-ionic effect confirmed that the starches were substantially free of fibre. The bulk density (w/w) is significant in relation to packing. The slight difference between the bulk density of PPS and the other two starches indicates that the PPS may require more packaging space. Low a_w suggests that the starches may be resistant to attack by most bacteria and many fungi. The starches, however, could be attacked and spoilt by xerophilic moulds which operate between 0.60 and 0.65 a_w (Troller, 1980). The WAC values obtained for the three starches were similar to the 78.2–92.4% reported by Naivikul and D'Appolonia (1979) for five different legume starches. The WOAI of the starches, being lower than two (De Kanterewicz et al., 1987), confirmed them to be lipophilic.

The photomicrographs, shown in Plate 1. indicate that the legume starches are morphologically irregular, oval and kidney-shaped. These shapes are confirmed by

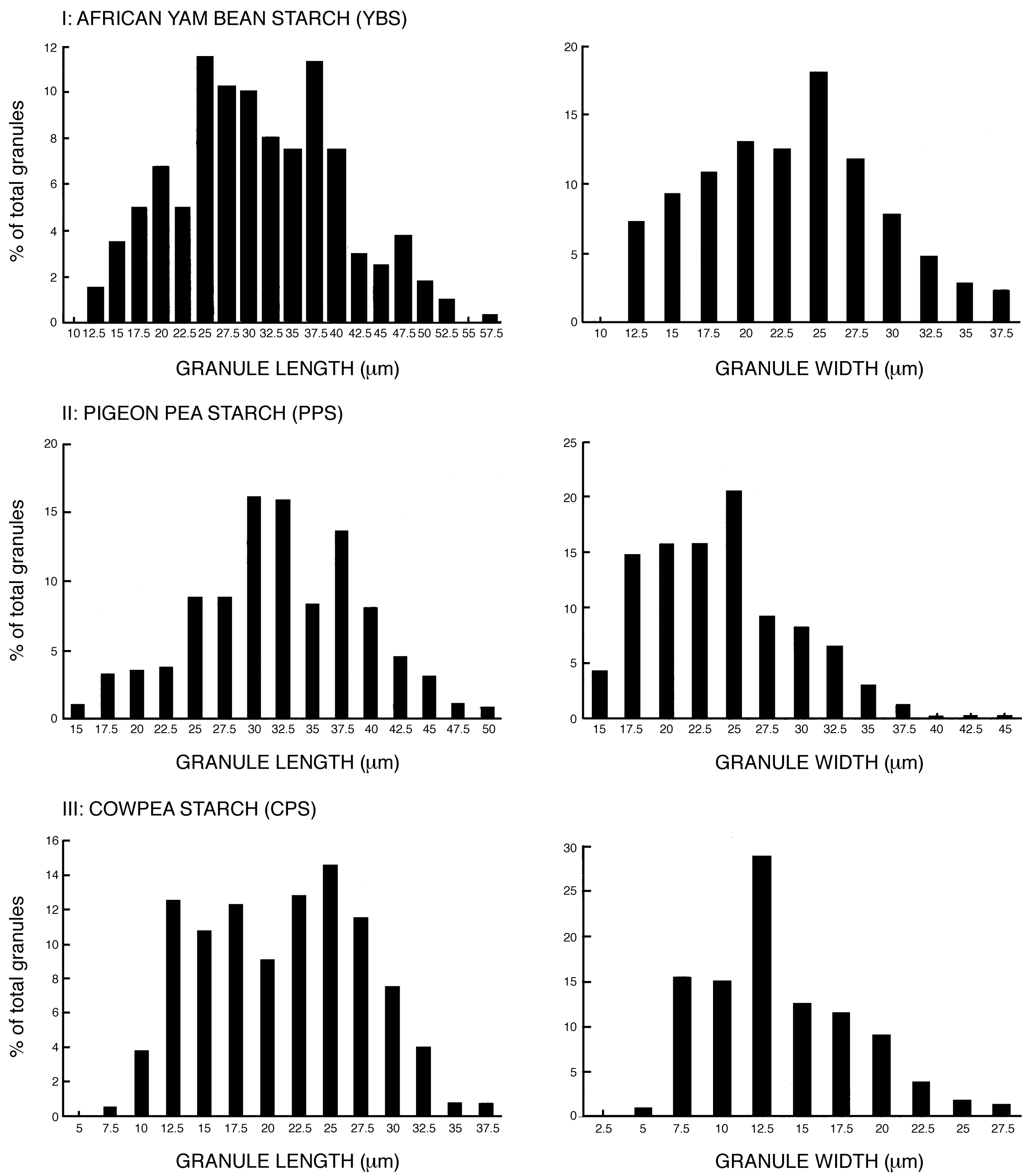

Fig. 1. Granule size distribution of unmodified starches.

the work of Naivikul and D'Appolonia (1979). Fissured granules are most conspicuous in CPS while in the YBS they are sparce, and are almost imperceptible in the PPS. The extent of fissure in granules is a direct result of drying (Hall & Sayre, 1971), probably signifying thatCPS may be the most vulnerable to solar drying. The lower degree of fissures in the granules, of Cita II PPS compared to the pigeon peas studied by Singh, Voraputhanporn, Rao, and Jambunathan (1989) may be attributed also to their differing susceptibility to drying effect or to their varietal variations. The PPS displays remarkable striation which distinguishes it from the other starches.

Fig. 1 shows the size distribution of the starch granules. The granule length in all starch samples are generally more distributed than their widths. The width distributions in both YBS and PPS are apparently similar and are slightly wider than that of CPS.

Table 2 shows the dimensions of all size classes of the three starches. CPS is permeated by relatively small-sized granules. The smallest granules of YBS and PPS are 12.5 and 15.0 μm, respectively, while their largest granules are 57.5 and 50 μm, respectively. The mean diameters of PPS and YBS are identical and are 1.55 times that of CPS. The physico-functional and nutritional implications of striation and granular size are yet to be elicited by research.

Fig. 2 indicates that the 6.2% aqueous concentrations of YBS, PPS ar l CPS exhibited type C viscosity patterns without a pasting peak but with a continual rise throughout the heating period. Similar amylogram results have seen previously reported (Schoch & Maywald, 1968; Vose, 1980; Lii & Chang, 1981; Dreher, Padmanaban, & Frazier, 1983).

The pasting characteristics of the three starches are shown in Table 3. The temperature at which CPS and YPS started to swell (their initial pasting temperatures) were lower than that of PPS which occurred at 85%. The pasting time for PPS was about two and four times longer than those of YBS and CPS, respectively. Since no definite peak was obtained in this study, the value at 95°C was reported as peak viscosity (vm). The peak and final viscosities of the starches when held for 20 min at 95°C (Vr) were more or less constant. When the starches were cooled to 50°C their viscosities (ve) increased considerably.

The three legume starches exhibited very low breakdown as shown by vm−vr values (0–30 Brabender pasting viscosity [BU]). Low breakdown indicates the stability of the swollen granules against disintegration during cooking, which is in agreement with the reports

Table 2
Granule sizes of isolated starches

Starch source	Diameter mean (μm)		Range diameter (μm)	
	Length	Width	Length	Width
Cowpea (Ife Brown)	22.58 ± 2.65	16.25 ± 2.40	7.5–37.5	5.0–27.5
Pigeon pea (Cita II)	34.06 ± 3.07	29.17 ± 2.71	15.0–50.0	15.0–45.0
Yambean	33.83 ± 3.20	25.00 ± 2.50	12.5–57.5	12.5–37.5

Values are size means ± standard error of 400 granules.

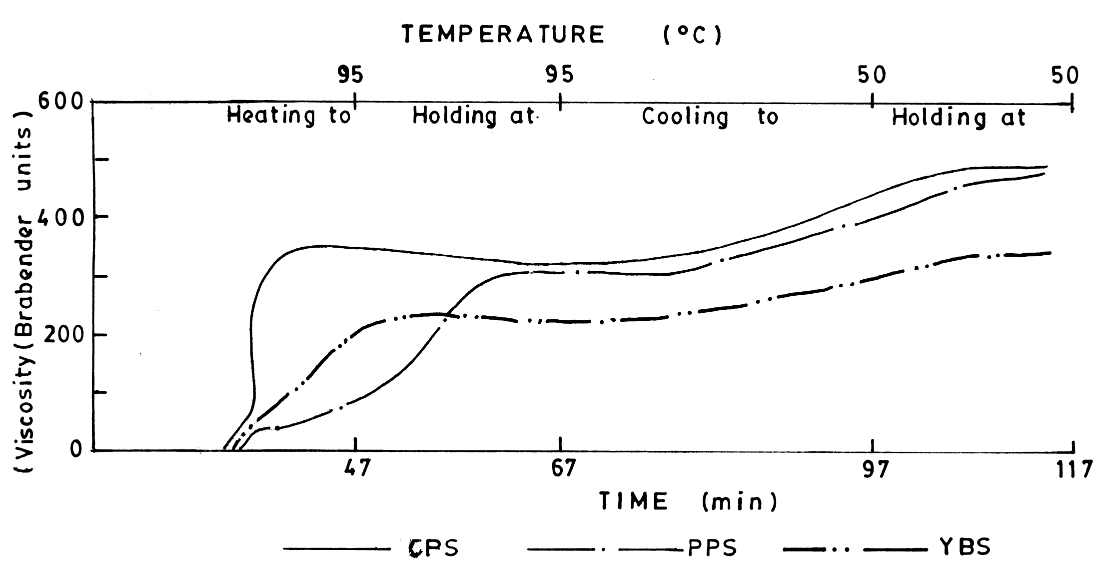

Fig. 2. Brabender viscosity of three legume starches.

Table 3
Pasting characteristics of cowpea, pigeon pea and yambean starches

	Initial pasting temperature (Tg) (°C)	Gelatinization time (Mg) (min)	Time taken to reach peak viscosity (Mn) (min)	Pasting time (Mn−Mg) (min)	Brabender pasting viscosities (Bu)					
					Max. on heating to 95°C (vm)	After 20 min at 95°C (vr)	Cooled to 50°C (ve)	Breakdown (vm−vr)	Setback (ve−vm)	Consistency (ve−vr)
Cow pea	76	34	41	7.00	340	310	480	30	40	170
Pigeon pea	85	40	67	27.00	306	306	478	0	172	172
Yambean	78	35.5	51	15.50	230	228	318	2	88	90

Determinations at 6.2% concentration/starch.

of Mazurs, Schoch, and Kite (1957), Adeyemi (1983) and Juliano (1985). YBS's tendency to gel (i.e. its consistency) denoted by the ve−vr value (90 Bu) was quite lower than that of the other starches with a ve−vr value of about 170 Bu. However, YBS displayed the least tendency to retrograde because it had a lower ve−vm value (88 Bu) than CPS and PPS which were 140 and 172 Bu, respectively.

The swelling capacities of the legume starches are presented in Fig. 3. At 60°C only very little change occurred, while at 70°C swelling of the CPS was most conspicuous with the PPS being least prone to swelling. At 80°C swelling of the starches became more marked and their order of swelling was CPS > YBS > PPS. At 90°C, although all the starches showed maximum swelling, the swelling of PPS was most appreciable between 80 and 90°C. The slow swelling pattern of the three starches at relatively low temperatures is confirmed by the report of Singh et al. (1989). The swelling behaviours of the starches may be affected by the structural arrangements of their constituent amylose and amylopectin (Schoch & Elder, 1955). Thus it is most probable that the granular arrangements of CPS are less compact and, therefore, may have higher intermolecular areas than the other two starches. When gelatinization temperature was reached the loose associative bonding in the open intermolecular areas was quickly modified by hydration, resulting in swelling of the granules (Schoch & Elder, 1955; Biliaderis, 1992). Conversely, the granules of YPS and PPS were presumed to be more strongly held together by intermolecular bonds and, therefore, became more crystalline and more resistant to swelling than CPS. Water binding increased as increasing temperature disrupted the intragranular bonds during the gelatinization process.

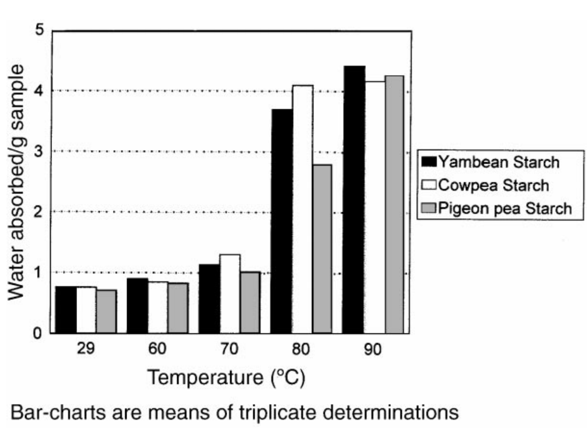

Fig. 3. Swelling capacities of three legume starches.

4. Conclusion

CPS, PPS and YPS exhibited: an appreciable shelf stability quality due to low a_w, WAC and OAC; and pasting characteristics with low set-back, low breakdown, restricted swelling at low starch–water concentration and temperature-dependent swelling. The distinct morphological and ionic characteristics of the legume starches are, respectively, good for indentifying their botanical origin and for detecting whether they are contaminated by or adulterated with starches from other sources. In the light of the good physico-functional attributes and reliable keeping qualities of the starches, their commercialisation may be exploited provided the grain legumes from which they are extracted are produced in excess of their conventional needs.

References

Adeyemi, I. A. (1983). Dry milling of sorghum for ogi manufacture. *Journal of Cereal Science, 1*.

Anderson, C. G. (1978). Non effect of dilute alkali solutions on the number of average granule diameters of some legume starches. *Journal of Food Technology, 13*, 217–223.

Biliaderis, C. G. (1992). Structures and phase transitions of starch in food systems. *Food Technology, June*, 98–109, 145.

Boulter, D., & Derbyshire, E. (1978). The general properties, classification and distribution of plant proteins. In G. Norton (Ed.), *Plant Proteins* (pp. 3–24). London: Butterworths.

De Kanterewicz, R. J., Elizalde, B. E., Pilosad, A. M. R., & Bartho-Lomai, E. B. (1987). A simple method for predicting the emulsifying capacity of food proteins. *Journal of Food Science, 52*, 1381–1383.

Dreher, M. L., Padmanaban, Q., & Frazier, R. A. (1983). Characteristics of pindax bean starch. *Journal of Agric. Food Chemistry, 31*, 844–846.

Duke, J. A., Okigbo, B. N., & Reed, C. F. (1977). The under exploited minor legumes; *Sphenostylis stenocarpa* (Hochst ex A. Rich) Harms (pp. 4–6). In *Tropical grain legume bulletin No. 10*. The international Grain Legume Information Center, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

Hall, D. M., & Sayre, J. (1971). A scanning electron. Microscope study of starches. Part III. Miscellaneous starches. *Textile Res. J., 41*, 880–883.

ICRISAT (1981). *Annual report 1980,* Patancheru A (p. 502) 32. India (p. 138). Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Juliano, B. O. (1985). Comparative tests on cooking properties of milled rice. *Cereal Food World, 30*, 651–654.

Kahn, V. I. (1987). Characterization of starch isolated from avocado seeds.. *Journal of Food Science, 52*, 1646–1.

Lii, C. Y., & Chang, S. M. (1981). Characterization of red bean (*Phaseolus radiatus* var. Aurea) Starch and its noodle quality. *Journal of Food Science, 46*, 78–81.

Lin, M. J. Y., Humbert, E. S., & Sosulski, F. W. (1974). Certain functional properties of sunflower meal products. *Journal of Food Science 39*, 368–370.

Lineback, D. R., & Ke, C. H. (1975). Starches and low molecular weight cabohydrates from chick pea and horse bean flours. *Cereal Chemistry, 52*, 334–347.

Longe, O. E. (1981). Carbohydrate composition of different varieties of cowpea (*Vigna unguiculata*). *Food Chemistry, 6*, 153–161.

Mazurs, E. G., Schoch, T. J., & Kite, F. E. (1957). Graphic analysis of the Brabender viscosity curves of various starches. *Cereal Chemistry, 34*, 141–152.

Naivikul, O., & D'Appolonia, B. L. (1979). Carbohydrates of legume flours II starch. *Cereal Chemistry, 56*, 24–28.

NAS (1979). Advisory Committee Reports on Tropical Legumes: Resources for the future of African yambean (pp. 27–32). Washington DC: National Academic of Sciences.

Norton, G., Bliss, F., & Bressani, R. (1985). Biochemical and Nutritional attributes of grain legumes. In R. J. Summerfield, & E. H. Roberts (Eds.), *Grain Legume Crops* (pp. 73–114.) London: Collins.

Okezie, B. O., & Bello, A. B. (1988). Physico-chemical and functional properties of winged bean flour and isolate compared with soy isolate. *Journal of Food Science, 53*, 450–452.

Quinn, J. R., & Paton, D. (1979). A practical measurement of water hydration capacity of protein materials. *Cereal Chemistry, 56*, 38–39.

Sathe, S. K., Iyer, V., & Salunkhe, D. K. (1981). Investigation of great Northern bean (*Phaseolus vulgaris* L.). Starch solubility, swelling interaction with free fatty acids and alkaline water retention capacity of blends with wheat flours. *Journal of Food Science, 46*, 1914–1917.

Schoch, T. J., & Elder, A. L. (1955). Starches in the food industry. In *Uses of sugar and other carbohydrates in the food industry. Adv. Chem. Ser., 12*, 21–34.

Schoch, T. J., & Maywald, E. C. (1968). Preparation and properties of various legume starches. *Cereal Chemistry, 45*, 564–573.

Singh, U., Voraputhanporn, W., Rao, P. V., & Jambunathan, R. (1989). Physico-chemical characteristics of pigeon pea and mung bean starches and their noodle quality. *Journal of Food Science, 54*, 1293–1297.

Troller, J. A. (1980). Influence of water activity on Micro-organisms in foods. *Food Technology, May*, 76–80.

Vose, J. R. (1980). Production and functionality of starches and proteins isolated from legume seeds (Field peas and horse beans). *Cereal Chemistry, 57*, 406–410.

Wurzburg, O. B. (1968). *Handbook of food addives*. Cleveland, OH: CRC Press.