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The Tensile Strength, Gelling Properties and Temperature Dependence of Solubility and Swelling Power of Five Legume Starches

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Abstract: The tensile strength, gelling properties and the effect of temperature on solubility and swelling power of starches of guard seed, white melon, yellow melon, benniseed and bulma cotton seed have been investigated. The results showed that bulma cotton starch has the highest tensile strength with the value of 0.081±0.02N/mm^2 while gourd seed has the lowest value of (0.015±0.001N/mm^2). Gourd starch has the best gell strength amongst the samples studied with value 4% w/v. Both the native and modified starches studied show remarkable increases in swelling power between 60-90°C. The oxidized starches is more soluble than the native starches due to weakening of the starch granules but also decrease swelling power of the starches studied. Acetylation of starches increases the swelling power and makes modified starches less soluble than the native starches.

Key words: Tensile, gelling, temperature, solubility, swelling, legume, starches

INTRODUCTION

Starch is a class of carbohydrates called polysaccharides which is found by larger condensation of sugars and are stored in liver and muscle of man (Ademuwagun *et al.*, 1978). Starch is an important ingredient for the food and allied industries.

Carbohydrates are the primary products of photosynthesis and are the most abundant food available to man. The presence of starch in any food can be tested positive when the product reacts to give purple colour on addition of iodine. As new food products are developed, starches with specific properties are necessary to impart functionality desirable attributes (Alves *et al.*, 1999) to pharmaceutical and food products. Some physical and chemical properties of several varieties of the starch have been reported (Goering and Dehaas, 1972; Higashilara *et al.*, 1978; Sugimoto *et al.*, 1986) and Sal and Dhupa seeds reported by Tharanathan *et al.* (1990).

The modern food processing industries are increasingly dependent in the use of both native and modified starches for production of formulated products. As a result, there is a great need to search for new and alternative sources of starch from underutilized and abundantly available food materials. The present work is concerned with isolation, modification and determination of gels, tensile strength and dependence of temperature on solubility and swelling. These food materials studied are commonly available leguminous crops and contain appreciable amount of oil and protein useful for commercial application and substitute for conventional food products.

MATERIALS AND METHODS

Gourd seed (A), white melon (B), yellow melon (C), Benniseed (D), were purchased from Oja Oba market in Akure, Ondo State while bulma cotton seed (E) was harvested in the compound of University of Ado-Ekiti, Ekiti State. The seeds were thoroughly sorted and screened to remove the bad seeds and dry milled into flours prior to analysis.

The isolation of the starch from the five legumes was carried out using the method described by Ogungbenle (2007). The acetylated and oxidized starches were obtained by following the procedure described by Ogungbenle (2007).

The gelling properties was determined using the method of Coffman and Garcia (1977) with slight modification. Starch slurries of the samples (2-20% w/v) were prepared in distilled water. Suspension (5cm^3) of each sample was put into test tubes and heated for 1hr in boiling water bath followed immediately by a rapid cooling in cold water bath. The test tubes were further cooled at 4°C for 2hr. The gel strength was determined as the test tubes whose the content did not slip off away when inverted.

The tensile strength of the starch samples was determined by measuring the tensile stress of the bond by use of a tension meter. The starch bonded specimen was hung between the pulleys by means of two hooks. The electrically operated instruments was switched on the main supply. The force acting on the specimen was monitored by tracing the mercury level as it rises along a calibrated scale. The rise of mercury was fairly rapid at the beginning of the measurement by gradual near the bond failure point. The distance moved by the lever is read from the scale (in tons). The tensile stress was calculated by dividing the breaking load or force (N) by the effective area of the bounded slabs.

$$\text{Tensile stress} = \frac{\text{Force (N)}}{\text{Area (mm}^2\text{)}}$$

Conversion: 1kg f = 9.8066N, 1 ton = 10,000N

The temperature dependence of solubility and swelling power of the sample starches were done by the procedure of Leach *et al.* (1959) with slight modification. Starch (1g) was accurately weighed and transferred into a clean dried test tube and weighed (w_1). The starch was then dispersed in $50cm^3$ of distilled water using blender. The resulting slurry was heated at desired temperature viz-a-viz 40, 50, 60, 70, 80 and 90°C for 30 min in a thermostated water bath. The mixture was cooled to room temperature and centrifuged at 2,200r.p.m for 15 min. Aliquot ($5cm^3$) of the supernatant was dried to a constant weight at 120°C. The residue obtained after drying the supernatant represented the amount of starch solubilized in water. Solubility was calculated as g per 100g of starch on dry basis. The residue obtained from the above experiment after centrifugation with water it retained was transferred to a clean, dried test-tube used earlier and reweighed (w_2).

$$\text{\% swelling of starch} = \frac{W_2 - W_1}{\text{weight of starch}} \times 100$$

RESULTS AND DISCUSSION

The gelling strength is presented in Table 1. The values were: gourd starch (4%w/v), white melon starch (6% w/v), yellow melon starch (6%w/v), benniseed starch (10% w/v) and bulma cotton starch (8% w/v) respectively. Gourd starch has the highest gel strength. Gelation involves the formation of a continuous network which exhibits certain degree of order. Sathe *et al.* (1982) associated the variation in gel formation of different leguminous flours to the relative ratios of the different constituents (proteins, carbohydrates and lipids) that make up the legumes. Gels are characterized by relatively high viscosity, plasticity and elasticity. It is interesting from the result that gourd starch has better ability to form gel and provide a structural matrix for holding water, flavours, sugar and food products (Circle *et al.*, 1964).

The values for the gel strengths were lower than those of Taro (1.8-2.7g) reported by Jane *et al.* (1992) and corn starch (10g) but Taro starch pastes set to weak gels. Among the samples starch studied, gourd starch, white, yellow melon and benniseed starches set to the strongest gels. The soft weak gel of bulma cotton starch may be desirable for use in frozen foods and desserts but other samples may be useful in stabilizing agent in food system such as pudding, creams and sauces which required thickening and gelling.

Table 2 shows the results of the tensile strength of the sample starches in N/mm^2. The values obtained varied between 0.015±0.001 and $0.0181\pm0.002N/mm^2$. The highest value was reported for bulma cotton starch while the lowest value was reported for gourd starch. The mechanical strength of starch applied between two surfaces provides a measure of the binding potential of the materials concerned. An excessively strong bond may prevent disintegration, subsequent dissolution and solubility (Timoshoenko and Goodier, 1985). The values for tensile strength of native starches of sorghum ($0.764MNm^{-2}$), Plantain ($1.026MNm^{-2}$) and Corn ($1.077MNm^{-2}$) reported by Alebiowu and Itiola (2002) are higher than those reported presently for starch of gourd seed, white melon, yellow melon, benniseed and bulma cotton seed. The low value reported for tensile strength of gourd seed ($0.015\pm0.001N/mm^2$) makes it desirable for lamination and capping during tablet formulation in pharmaceutical industry and allows chipping of compact during transportation (Hiestand *et al.*, 1977). When the starches with low tensile strength are added to products, this tends to lower the bond strength of the products (Itiola, 1991) and since higher tensile strength value implies higher total plastic deformation which would lead to more contact points for interparticulate bonding (Itiola and Pipel, 1991; Alebiowu and Itiola, 2002). It can be observed from the results that bulma and benniseed starches would be useful in wood and paper mill industries because of their fairly high binding ability and high tensile strength bonds between two soft wooden slabs and surface applied.

The dependence of temperature on solubility as depicted in Fig. 1.

The pattern of solubilization of the starches are influenced by the type and species of the granules of the starches studied. The plots of solubilities of the five starches against temperature are similar to their swelling patterns as rightly observed by Leach *et al.* (1959) for milo and waxy white milo starches. For all the sample starches studied, solubilities increased as temperature increased.

The hypochlorite oxidized starches recorded increased solubilities when compared to the native starches. This may be due to the weakening of the starch granules during oxidation leading to improved solubility. Solubility characteristics of starch acetates are reported to depend on the level of substitution and polymerization (Krugger and Ruttenberg, 1967).

The effect of temperature on swelling power of the starches is shown in Fig. 2. The pattern of swelling is affected by the species and types of starches. Each specie of starch swells differently showing variableness in the arrangement of the granules within the starches. Yellow melon starch undergoes a very rapid and almost unrestricted swelling at relatively low temperature. This indicates weak bonding forces of approximately uniform strength (Leach *et al.*, 1959). Bulma cotton starch and gourd starch commenced to swell at almost the same temperature as yellow melon, but the swelling thereafter proceed at a much slower rate. Hence, it is therefore presumed that the associative forces within the bulma

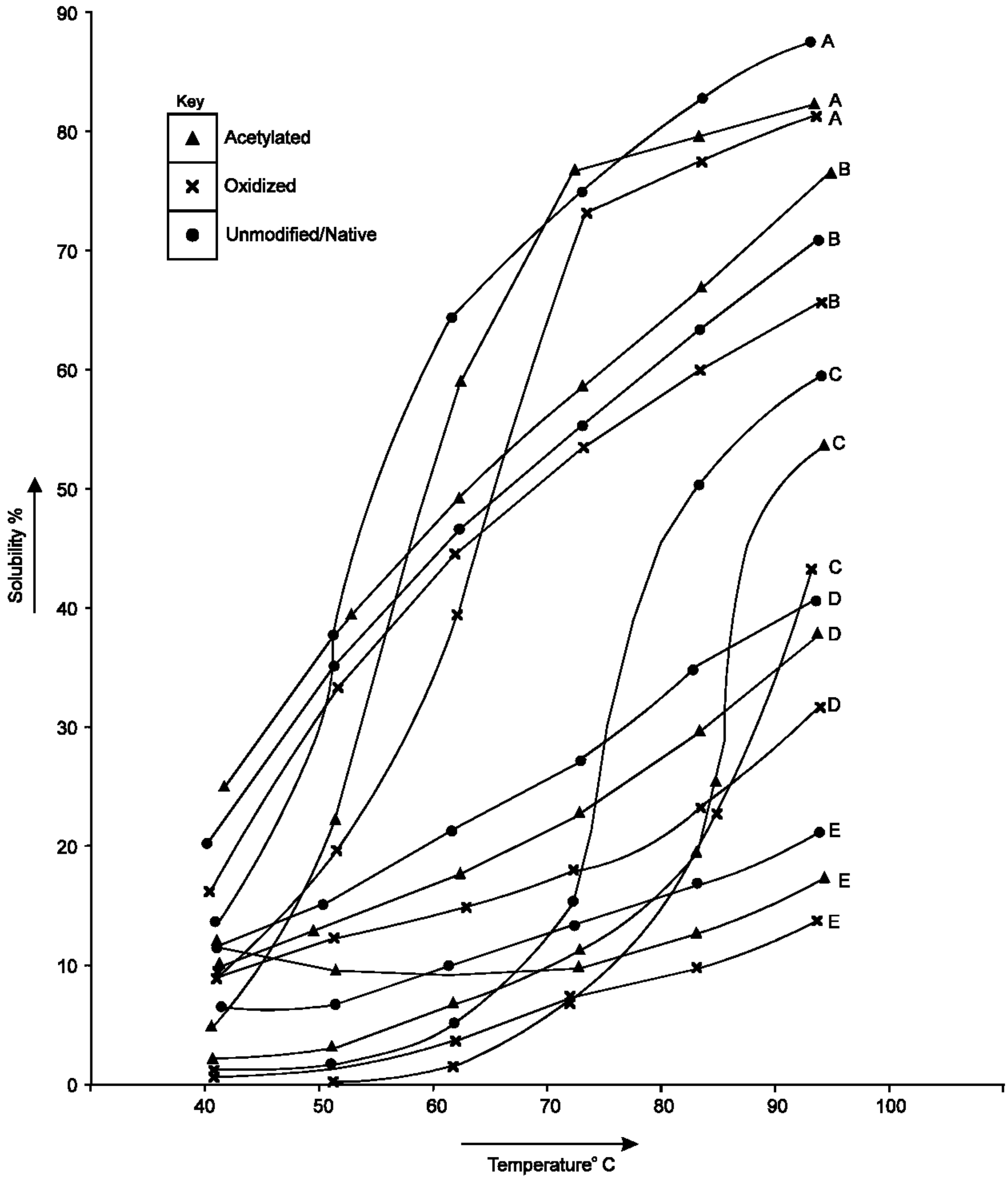

Fig. 1: Effect of temperature on solubility of the starches.

cotton and gourd starch granules represent a much wider range of bond strength than those in yellow melon starch. The two different starch granules may be likened to two liquids, having a narrow and a wide range of distillation respectively (Sugimoto *et al.,* 1986). These starches show initial gelatinization, then a period of restricted swelling and finally a second rapid swelling. This behaviour is attributed to two sets of bonding forces which relax at different temperatures and wax stronger, persisting until 80-90°C. Benniseed starch shows a pattern similar to that of bulma cotton starch but with much restricted swelling due to highly associated starch granule that is relatively resistant to swelling.

The modified and native starches studied showed

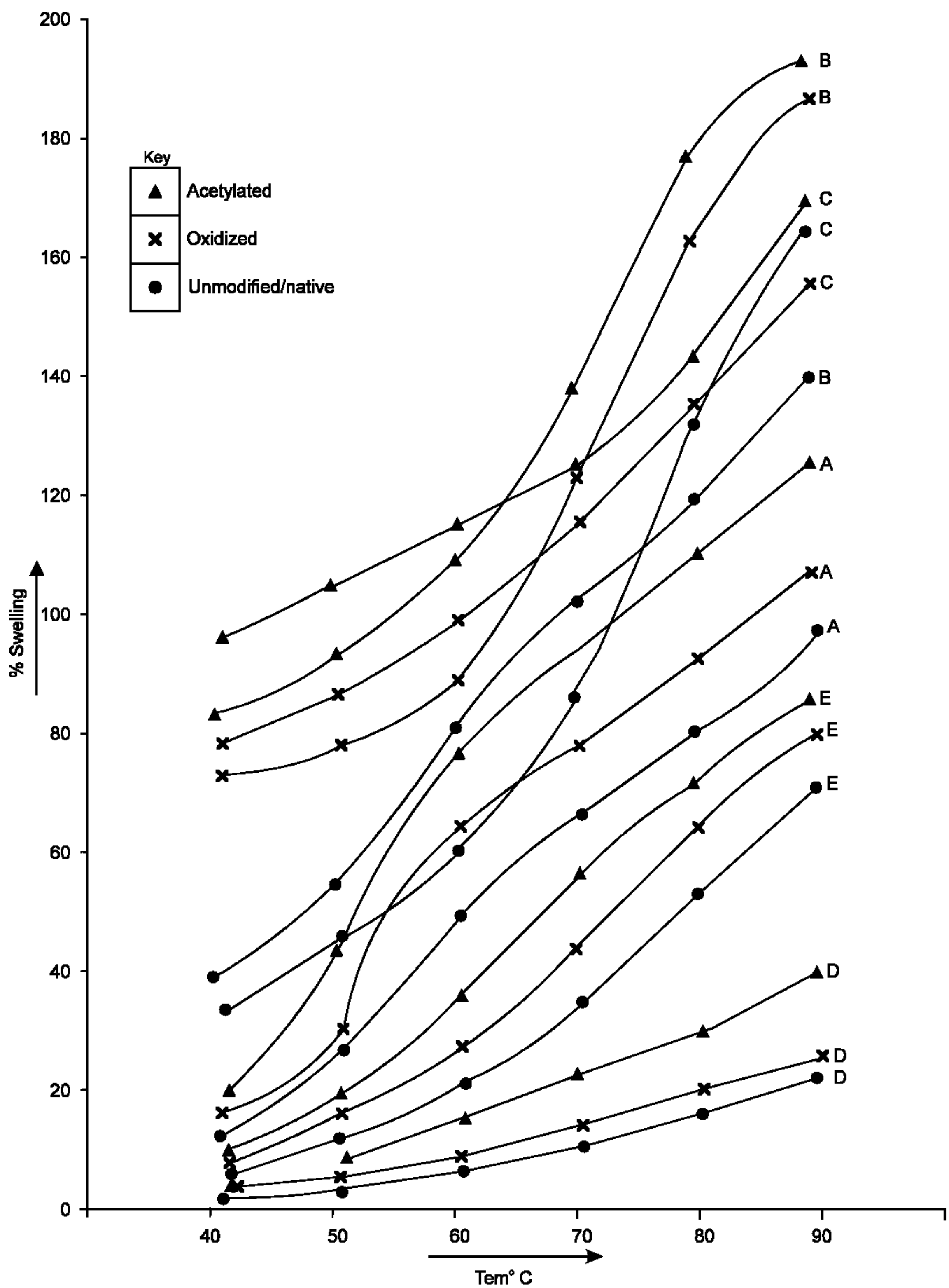

Fig. 2: Effect of temperature on the swelling pattern of the starches.

remarkable increases in swelling power between 60-90°C. This is similar to the observation of some earlier workers of some legume starches which occurred within the range of 60-90°C (Hoover and Sosulki, 1991; Schoch

Table 1: Gel strength of the sample starches

Concentration % w/v		2.0	4.0	6.0	8.0	10.0	12.0
Gourd Seed Starch (A)	Observation	Viscous	Gel	Gel	Gel	Firm Gel	Firm Gel
	Inference	-	+	+ (Lgc)	+	+	+
White Melon Starch (B)	Observation	Viscous	Viscous	Gel	Gel	Gel	Firm Gel
	Inference	-	-	+ (Lgc)	+	+	+
Yellow Melon Starch (C)	Observation	Liquid	Viscous	Gel	Gel	Gel	Gel
	Inference	-	-	+ (Lgc)	+	+	+
Benniseed Starch (D)	Observation	Liquid	Liquid	Liquid	Viscous	Gel	Gel
	Inference	-	-	-	-	+ (Lgc)	+
Bulma Cotton Starch (E)	Observation	Liquid	Viscous	Viscous	Gel	Firm Gel	Firm Gel
	Inference	-	-	-	+ (Lgc)	+	+

Table 2: Tensile Strength of the Sample Starches

Starch	Tensile Strength (N/mm^2)
Gourd Seed (A)	0.015 ± 0.001
White Melon (B)	0.022 ± 0.002
Yellow Melon (C)	0.040±0.001
Benniseed (D)	0.075±0.003
Bulma Cotton Seed (E)	0.081±0.002

Lgc: least gel concentration, A = Gourd Starch, B = White Melon Starch, C = Yellow melon Starch, D = Benniseed, E = Bulma Cotton Starch.

and Maywald, 1968; Wankhede and Ramteke, 1982). There was increased entropy which offset the hydrogen bonding occurring in the crystalline regions, thereby increased the swelling power. The difference in the swelling patterns of the starches suggest that the level of crystalline packing to the granules of the starches of the samples follow this order, yellow melon starch > white melon starch > gourd starch > bulma cotton starch > benniseed starch.

It can be concluded that acetylation of starch increases the swelling power while oxidation decreases the swelling power for all the legume starches studied. Hypochlorite oxidation may likewise be a highly effective means for weakening the internal structure of starch granules (Leach *et al*., 1959), which thereby making the starch more soluble but with much decreased power to swell. Acetylation of starch caused an increased viscosity due to the linear fraction of the starch that is modified. The properties of the starches compared favourably with conventional starchy foods.

The starch from bulma seed has high tensile strength which may increase the bond strength of most textile materials on adding the starch during yarning and printing of fabric while low tensile strength of the gourd seed starch makes it suitable for tablet formulations in pharmaceutical industry.

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