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Studies on the Gelatinization Temperature of Some Cereal Starches

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Abstract

Gelatinization temperature of starches from different varieties of cereals, deep-red sorghum, red sorghum, white sorghum, mixed sorghum, white fonio (*Digitaria exilis*), black fonio (*Digitaria iburua*), *Eleusine coracana* (tamba), proso millet (*p. miliacium*), brown top millet (*p. ramosum*) and finger millet (*Eleusine coracana*) were determined by electrical conductivity (EC) method. Among the untreated starches, the results showed that tamba recorded the least onset and peak gelatinization temperatures of 53.0^{o}C and 63.0^{o}C respectively while the highest onset gelatinization temperature, 76^{o}C was recorded with proso millet. Proso millet and finger millet had the highest peak gelatinization temperature. deep-red sorghum and red sorghum had the least end gelatinization temperature while proso millet recorded the highest value. The 0.1MKCl treatment of cereals starches produced elevated onset gelatinization temperatures (62.0-78.0^{o}C). Mixed sorghum had the least onset gelatinization temperature while proso millet and finger millet recorded the highest gelatinization temperature. Following the 0.1MKCl treatment, starches from tamba and proso millet recorded the least and highest peak gelatinization temperatures respectively. Deep-red and red sorghum recorded the least end gelatinization temperatures while proso millet, brown top millet and finger millet recorded the highest end gelatinization temperatures. The treatment of the cereals starches with 0.10MKCl significantly ($p < 0.05$) delayed the onset gelatinization temperature of the starches and narrowed the gelatinization temperature range. The results of the conductivity of both the 0.1MKCl treated and untreated starch showed nonlinearity within the gelatinization range. This finding has important implication on the energy and time requirement to gelatinize the starch for specific industrial use.

Keywords: cereals starch, electrical conductivity, gelatinization temperature

1. Introduction

Starch occurs as highly organized structures, known as starch granules. Starch has unique thermal properties and functionality that have permitted its wide use in food products and industrial applications. When heated in water, starch undergoes a transition process, during which the granules break down into a mixture of polymers-in-solution, known as gelatinization. Starch gelatinization is a process that breaks down the intermolecular bonds of starch molecules in the presence of water and heat, allowing the hydrogen bonding sites (the hydroxyl hydrogen and oxygen) to engage more water (Sobkowska, 2001). Gelatinization temperature is regarded as the temperature at which the phase transition of starch granules from an ordered state to a disordered state occurs. The gelatinization temperature of starch depends upon plant type and the amount of water present, pH, types and concentrations of salt, sugar, fat and protein in the recipe, degree of cross-linking of the amylopectin, the amount of damaged starch granules as well as derivatisation technology used (Hermansson & Svegmark, 1996; Delcour et al., 2000). Almeida-Dominguez et al. (1997) reported that larger and more compact corn particles required additional time and energy for hydration preceding swelling and gelatinization. Thus, a proper understanding of starch phase transitions is extremely important in food processing (Singh et al., 2003). Native starch is not widely used in the food industry due to its poor functional properties and hence, most starches currently incorporated into foods are chemically modified (Coral et al., 2009).

Starch functionalities are very often decisive for rheological properties of foods. As a thickener, starch modifies food viscosity and affects texture and structure of foods. The modifications are seen as gelatinization, thickening, and elevated resistance to heating, shock, and ageing (Tomasik, 2000). This is particularly important for the quality of sauces, dressings, puddings, jams, jellies (Luallen, 2000). Processing technologies and quality of products from cereal and potato materials containing starch as a reserve substance are directly related to properties of the polysaccharide in question (Hermansson & Svegmark, 1996; Delcour et al., 2000).

Corn starch has been considered as a valuable ingredient to the food industry, being widely used as a thickener, gelling agent, bulking agent and water retention agent (Singh, 2003). The rising cost of sugar and the increased availability of corn syrups have raised interest in the substitution of corn syrup for sucrose in bakery items, especially in such high-sugar items as cakes. However, to satisfactorily replace sucrose in cakes, corn syrup must perform most of the same functions as sucrose in the cake system. In this wise, an important function is the proper understanding and control of starch gelatinization (Spies & Hoseney, 1982). Furthermore, starch-sugar interactions play a significant role in delaying starch gelatinization; thus, increasing the energy required for gelatinization and consequently, the cost.

According to Ubwa et al. (2011), the determination of gelatinization temperatures of some species of maize (*Zea mays* L) and sorghum (*Sorghum bicolor* L) obtained from Guma local government area of Benue State revealed the gelatinization temperature of white maize as 72-78^{o}C, yellow maize, 66-72^{o}C, white sorghum, 74-82^{o}C; and brown sorghum, 74-82^{o}C. It was concluded that yellow maize could readily be converted into sugars because of the least gelatinization temperatures.

Morales-Sanchez et al. (2009) carried out wet method for measuring starch gelatinization temperature using electrical conductivity and found the gelatinization temperatures for potato, 55-66℃; wheat, 52-66℃; corn, 66.2-77℃; and rice, 66-82℃. The result so obtained was compared with the gelatinization temperatures (onset, peak, and end) of Differential Scanning Calorimetry (DSC) method, with no significant differences. This indicates that electrical conductivity is indeed a precise method that can have certain advantages, especially in wet starch systems. Methods that can be used in the determination of gelatinization temperatures of starches are; The Differential Scanning Calorimetry method, Falling Number method, Ultrasound Technique, Alkaline Spreading Value, The Brabender Viscograph, electrical conductivity and photoelectric (Ubwa et al., 2011; Ratnayake & Jackson, 2006).

Unmodified starch can be used in the pharmaceutical, paper, mining and building industries—it can be modified and converted to starch derivatives, isosugar, high fructose syrup and ethanol (Interactive European Network for Industrial Crops and their Application, 2003).

Works on gelatinization temperatures of starch have been done elsewhere particularly on improved corn varieties but data were scanty on gelatinization temperature of local corn starches. Thus, this work determined gelatinization temperatures of starches from different varieties of cereals, deep-red sorghum, red sorghum, white sorghum, mixed sorghum, white Fonio (*Digitaria exilis*), black Fonio (*Digitaria iburua*) and *Eleusine coracana* (tamba), proso millet *(p. miliacium),* brown top millet *(p. ramosum)* and finger millet *(Eleusine coracana)* by electrical conductivity method; with a view to identifying species with lower gelatinization temperature, which will therefore reduce the cost of food processing in the food industries and increase the rate of digestion in animals. It also sought to know if the starch sources are suitable for use in pharmaceutical industry as binder and in drug coating.

2. Materials and Methods

2.1 Area Description

The study areas consist of Buruku Local Government Area (Benue state), Pankshin, Barkin Ladi, Shendam, Jos South, Langtan North and Langtan South Local Government Areas (Plateau). Some important data about the areas are presented in Table 1.

2.2 Sample Collection and Preparation

Bulk samples of Sorghum were collected from four sampling areas (sampling stations) as follows; white sorghum (Pankshin Local Government), mixed red and pale-yellow sorghum (mai edon toro) (Barkin Ladi Local Government), deep-red sorghum (Langtan local government) and red sorghum (Shendam Local Government) of Plateau State. Black and white Fonio and tamba were collected from Jos south local government of Plateau State. Proso millet*,* brown top millet and finger millet were all collected from Etulo in Buruku local Government of Benue state. In each of this Local Government, 150 g sample of each species were collected from four different sampling stations and pooled together. Grains were carefully sorted to remove damaged kernels and debris (Okolo, 1997). The samples were milled into flour and 0.5 g of each species was measured and labeled in a beaker.

Table 1. Coordinates, total land areas and population of the study area

Study Area	Latitude	Longitude	Population NIPOST, 2009	Land Area
Buruku	7^o 07'–7^o 44' N	8^o 45'–9^o 36' E	203,721	1,246 km^2
Pankshin	9^o 14'–9^o 36 ' N	9^o 20'–9^o 44' E	191,685	1, 524 km^2
Barkin Ladi	9^o 26'–9^o 46' N	8^o 53'–9^o 14' E	175,267	1,032 km^2
Shendam	8^o 45'–9^o 15' N	9^o 20'–9^o 45' E	208,017	2,477 km^2
Jos South	9^o 36'–9^o 55' N	8^o 37'–9^o 07' E	306,716	510 km^2
Langtan North	9^o 08' N	9^o 47' E	140,643	1, 188 km^2
Langtan South	8^o 38' N	9^o 48' E	106, 305	838 km^2

2.3 Procedure

The procedure used was the one reported by Li et al. (2004) with some slight modifications. 125 cm^3 of distilled water was poured in 250 cm^3 wide-mouthed flasks (reaction vessel) and suspended in a 1000 cm^3 Pyrex beaker which served as the water bath. It was then placed on a three-heat hot plate, and the conductivity meter probe was dipped into the reaction vessel. The hot plate was adjusted to give a degree Celsius rise in temperature per minute. When the temperature in the reaction vessel had reached 45^{o}C, cereal flour of 0.5 g was suspended in 25cm^3 of distilled water and slowly poured into the reaction vessel. The conductivities of the mixture were recorded degree Celsius rise interval till the Gelatinization temperature was obtained.

3. Results and Discussion

3.1 Results

The gelatinization temperatures and electrical conductivities of some cereals starch and the effects of treatment with 0.10M KCl on the gelatinization temperatures of starches of some cereals obtained from farmers in six different Local Government Areas of plateau State and Etulo (Buruku Local Government Area) of Benue State are presented in Tables 1 and 2. The result in Figures 1 – 3 present the t-test analysis of the effects of the 0.1MKCl treatment on the onset, peak and end gelatinization temperatures respectively.

Table 2. Gelatinization temperatures and electrical conductivities of starch from different cereals starch

Variety	T_o(^{o}C)	I_o(μS)	T_p(^{o}C)	I_p(μS)	T_e(^{o}C)	I_e(μS)	R
Deep-red Sorghum	64.0	28.9	70.0	31.2	76.0	31.5	12
Red Sorghum	64.0	55.3	72.0	58.5	76.0	60.2	12
White Sorghum	66.0	42.7	72.0	43.7	78.0	44.7	12
Mixed Sorghum	60.0	44.4	72.0	45.8	78.0	46.0	18
White Fonio	60.0	30.0	72.0	33.6	78.0	33.5	18
Black Fonio	60.0	23.5	74.0	26.9	82.0	26.8	22
Tamba	53.0	4.8	63.0	5.8	77.0	4.1	24
Proso millet	76.0	36.7	86.0	36.6	87.3	39.3	11.3
Brown top millet	72.0	39.0	84.0	39.3	86.0	40.3	14
Finger millet	74.0	39.0	86.0	42.2	87.1	42.3	13.1

Table 3. Effect of 0.1M KCl on gelatinization temperatures and electrical conductivities from different cereals starch

Variety	T_o(°C)	I_o(μS)	T_p(°C)	I_p(μS)	T_e(°C)	I_e(μS)	R
Deep-red Sorghum	70.0	1106	74.0	1192	76.0	1123	6
Red Sorghum	66.0	1164	72.0	1225	76.0	1325	10
White Sorghum	66.0	959	74.0	1015	78.0	1095	12
Mixed Sorghum	62.0	1034	74.0	1214	78.0	1171	16
White Fonio	64.0	1015	78.0	1132	80.0	1131	16
Black Fonio	64.0	906	80.0	1037	84.0	1140	20
Tamba	66.0	1010	70.0	1025	80.0	1023	14
Proso millet	78.0	1274	85.0	1289	86.0	1295	8
Brown top millet	76.0	1218	84.0	1332	86.0	1340	10
Finger millet	78.0	1042	84.0	1050	86.0	1110	10

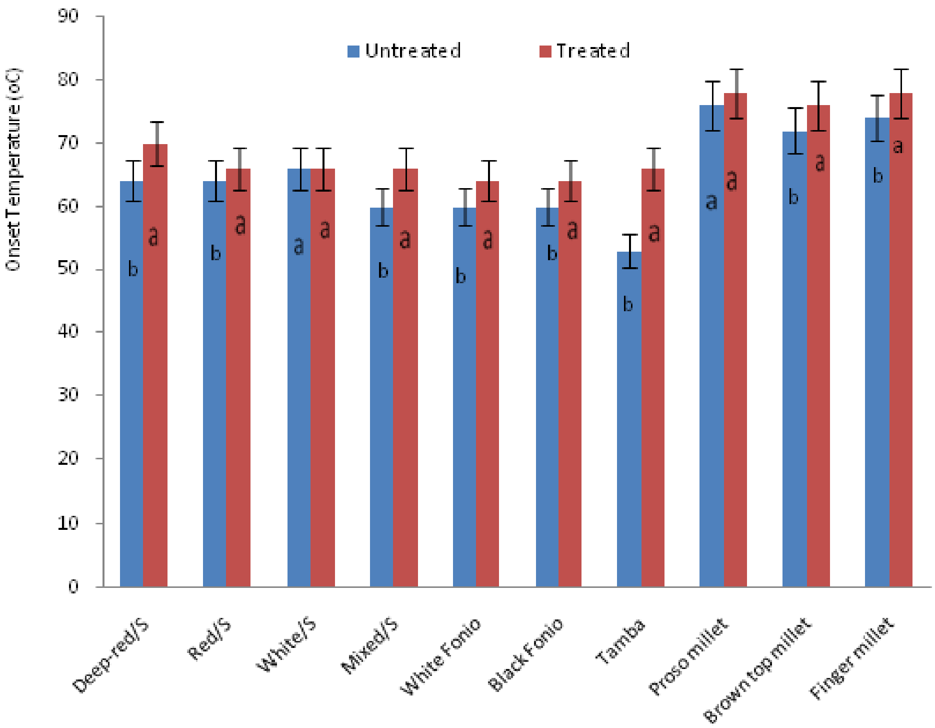

Figure 1. Effect of 0.1M KCl on onset gelatinization temperature of some cereals starch

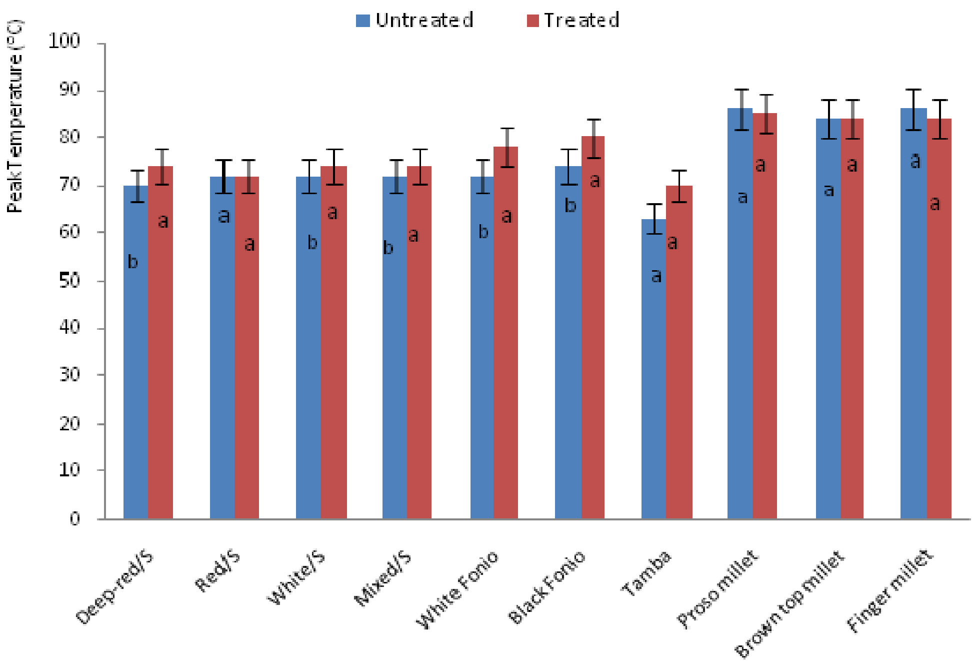

Figure 2. Effect of 0.1M KCl on peak gelatinization temperature of some cereals starch

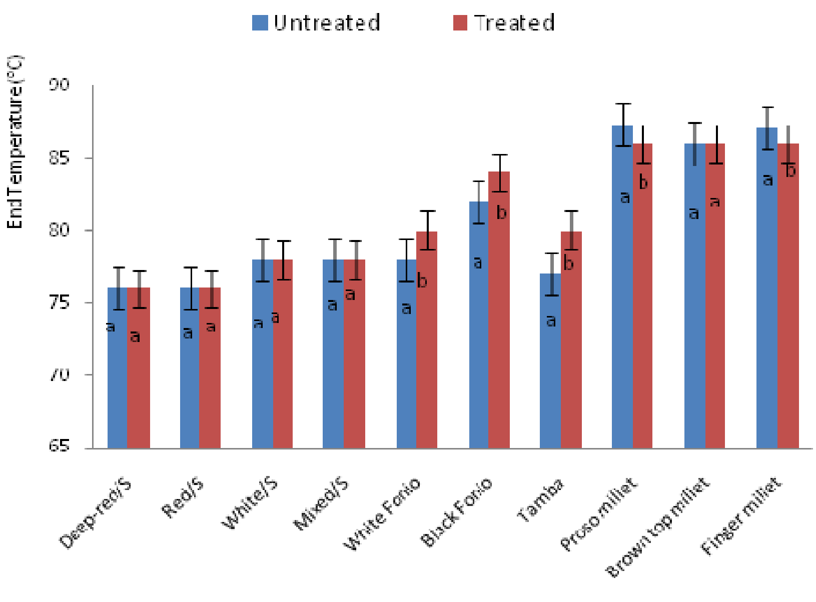

Figure 3. Effect of 0.1M KCl on the end gelatinization temperature of some cereals starch

Key: Results of t-test analyses with the same alphabets are statistically significant ($p < 0.05$).

3.2 Discussion

The results of this study showed that tamba recorded the least onset and peak gelatinization temperatures of 53.0°C and 63.0°C respectively. The highest onset gelatinization temperature (76.0°C) was recorded in Proso millet but Proso millet and Finger millet had the highest peak gelatinization temperature (86°C). Deep-red Sorghum and Red Sorghum at 76.0°C had the least end gelatinization temperature while Proso millet with end gelatinization temperature of 87.3°C was the highest recorded value (Ubwa et al., 2011; Morales-Sanchez et al., 2009).

The results in Table 2 show the effect of 0.10M KCl on the gelatinization temperatures of the starches. Generally, there was delay of the onset gelatinization temperatures in all the cereal starches. Thus, the onset gelatinization temperatures recorded elevated values (62.0^{o}C–78.0^{o}C) following the treatment. In a similar study, Chungcharoen and Lund (1987) noted that the treatment of rice flour with sodium chloride in the ratio of 0.04:1 increased the gelatinization temperature but decreased the enthalpy of transition in the rice flour and isolated starch samples. It was reported that the influence of ionic and non-ionic solutes on starch gelatinization greatly altered the gelatinization characteristics. Chinachoti et al. (1991) also reported a shift of onset gelatinization temperatures to higher values following treatment with sucrose. Rahman (1995) reported that starch gelatinization is affected by various electrolytes, and the effects depend on the concentration and type of anions and cations. Also according to (Jane, 1993), neutral salts affect the onset gelatinization temperatures and heat of transition during corn starch gelatinization, and the effects differed by type and concentration of the salt. Mixed Sorghum had the least onset gelatinization temperature of 62.0^{o}C while Proso millet and Finger millet recorded the highest onset gelatinization temperature of 78.0^{o}C after the treatment. Tamba had the least peak gelatinization temperature of 70.0^{o}C after addition of the salt. Proso millet gave the highest peak gelatinization temperature value (85.0^{o}C). Deep-red Sorghum and Red Sorghum showed the least end gelatinization temperature of 76.0^{o}C. Proso millet, brown top millet and Finger millet had the highest end gelatinization temperature of 86.0^{o}C observed in this study. In general the gelatinization temperature ranges become smaller as result of salt addition.

The T-test analysis of the effect of the salt on the onset gelatinization temperature of the starches (Figure 1) was statistically significant ($p < 0.05$) for most of the starches except sorghum and Proso millet. Peak gelatinization temperature of White sorghum, mixed sorghum, White Fonio and Black Fonio differed significantly ($p < 0.05$) for the treated and untreated starches as presented in Figure 2. Addition of the salt showed no significant effect on the peak gelatinization temperatures of Deep - red sorghum, Red sorghum, Tamba, Proso millet, Brown top millet and Finger millet. Only White Fonio, Black Fonio, Tamba, proso millet and Finger millet showed significant difference in their end gelatinization temperatures (Figure 3) following the 0.1MKCl treatment.

The results of the conductivity of both the 0.1MKCl treated and untreated starch showed nonlinearity within the gelatinization range. This agrees with the findings of (Li et al., 2004) that during ohmic heating, there was nonlinear relationship between electrical conductivity and the gelatinization temperature range. However, the addition of 0.1M KCl to the starch significantly increased the electrical conductivity during the gelatinization range.

4. Conclusion

Treatment of the starches with 0.100M KCl delays the gelatinization temperatures of the starches mostly at the onset. Consequently, the gelatinization temperature ranges become smaller and this has important implication on the energy and time required to gelatinize the starch for specific industrial use.

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