Effect of sprouting days on the chemical and physicochemical properties of maize starch

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ABSTRACT

In this study, maize grains were sprouted for 3 to 7 days, wet milled and starch extracted was dried. The chemical composition and physicochemical properties of the starches were determined. The result of revealed that the moisture content for the starches from sprouted maize ranged between 13.33% and 12.16%. The values for the protein content for the maize starches ranged between 4.21% and 4.4%. The ash content values ranged 0.28% and 0.42%. The fat content of the starches ranged between 3.71%, and 2.17%, the carbohydrate content of the maize starches ranged between 78.91% and 80.69%. The amylose content of the maize starches ranged between 22.81% and 25.49% and their amylopectin values ranged between 77.19% and 74.51%.

The results for the physicochemical properties of maize starches show that the values of the bulk density, tapped density and Carr index ranged between 0.30g/ml and 0.25g/ml, 0.38g/ml and 0.31g/ml and 23.53% and 17.65% respectively. The water absorption capacities of the maize starches ranged between 96.22% and 100.51% Hydration capacity values ranged between 96.69% and 218.29%. The values for the swelling profile and solubility index of sorghum starches at different temperatures show a progressive increase in values with sorghum starch sprouted for 3 days having the highest values while sorghum starch sprouted for 7 days has the lowest values. A very sharp increase was observed in the result for the 80^{0}C for the starches for both swelling profile and solubility index.

Key words: Malting period, Physicochemical Properties, Maize starch

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INTRODUCTION

Maize is the third most important cereal after wheat and rice. The production of maize in the world was 721,000,000 acreage (FAO, 2004). Maize is an important food crop not only because it is consumed worldwide, but also due to its nutritive value. It provides more carbohydrate than wheat and sorghum and it is a good source of phosphorus. It also contains small amount of calcium, iron, thiamine, niacin, and fat (Adeyemo, 1984; Brandes, 1992). Reports show that maize is an important staple food crop in Africa (Adeyemo, 1984; Olakojo *et al.*, 2005), and it is an important food and feed crop in Nigeria and remains an important crop for rural food security. It is a staple food of great socio-economic importance in developing countries and it has a wide range of uses including: baking, brewing, starch production and livestock feed. The importance of maize cannot be over emphasized, with Nigeria producing about 43% of maize grown in West Africa. Maize is the most important staple food in Nigeria which accounts for about 43% of caloric intake (Nweke *et al*., 1983; NARP, 1994).

Starch, the main plant carbohydrate, is the most important plant derivative used by man and has unlimited importance in the food industry and can be modified to suit various applications using inexpensive methods, making it ideal for a number of uses. Starch is a semi-crystalline biopolymer and it is stored in various plant locations e.g. in cereal grains, roots, tubers, stem pith, leaves, seeds, fruit, and pollens (Jayakody and Hoover, 2008). The chemical composition, structure, and properties of starch are essentially typical of biological origin of the starch (Smith, 2001). Starch owes much of its functionality to high-molecular-weight carbohydrate components amylose and amylopectin and to the physical organization of these macromolecules in the granular structure (French, 1984). When starch is boiled in excess water, the granules swell, and at the same time, part of the components solubilized, giving a suspension of swollen particles dispersed in macromolecular continuous phase (Thebaudin, 1998). Textural changes of starchy products are mainly associated with starch gelatinization and retrogradation (Kim *et al*., 1997).

The importance of starch as a foodstuff may be judged by the fact that it accounts for over 30% of the average diet on a dry weight basis and more than 25% on an available energy basis (Galliard, 1987). Unmodified starches have limited usage due to its inherent weakness of hydrations, swelling and structural organization. Utilization of native starch is limited due to its weak-bodies, cohesive, rubbery paste and undesirable gels when cooked (Sriroth *et al*., 2002). To enhance viscosity, texture, stability, among many desired functional properties for many food and industrial applications, starch and their derivatives are modified by chemical, physical, and biotechnological means. However, there is increasing awareness on the danger of chemically modified starches in food components (Jaspreet, 2007). This has therefore led to the increased awareness on physical modification (Ikegwu *et al*., 2011). Processing methods such as soaking, sprouting and fermentation has been reported to improve the nutritional and functional properties of plant seeds (Jirapa et al., 2001). The thrust of this study is therefore to investigate the effect of malting periods on the chemical and physico-chemical properties of maize starches.

MATERIALS AND METHODS

Materials

White maize were purchased from Owena market in Oriade LGA of Osun State. The materials were sorted, cleaned and kept in high density polyethylene to avoid moisture uptake and contamination before use.

Method

Sprouting of cereal grains

The samples (1kg) were steeped in water at room temperature for 48 h and then spread (1mm thickness) to sprout for between 24 h to 168 h at room temperature inside the Food Processing Laboratory at Joseph Ayo Babalola University, Ikeji Arakeji, Osun State, Nigeria.

Production of starch

Starch was extracted from the sprouted samples after 72 h, 120 h, and 168 h according to the procedure of Singh *et al*, (2009) with slight modification. The flow chart for the production of the starch is shown in Fig.1. The maize grains were wet milled into smooth paste and mixed with clean water (about 5 times the weight of the grains). It was filtered through muslin cloth and allowed to settle. The supernatant was decanted and the sediment was dewatered with cheese cloth and the starch residue washed three times with clean water. The starch cake was broken, spread thinly on trays and dried in a cabinet dryer at 40 ^{0}C for 24 h. The dried starch samples were milled with blender (Marlex, Ecella model, Kanchan International Limited, Daman, India) and sieved through 100µ sifter then packaged in high density polyethylene bags prior to further analysis.

Cereal grains (Maize)
↓
Sorting
↓
Cleaning
↓
Steeping (48 hrs)
↓
Sprouting (24hrs – 168hrs)
↓
Wet Milling
↓
Mixing (with clean water)
↓
Filtering (with muslin cloth)
↓
Decanting
↓
Wet Starch
↓
Drying (40^{0}C)
↓
Dry Starch
↓
Milling
↓
Sieving
↓
Packaging

Fig 1: Flow chart for the production of starch from sprouted sorghum and maize. (Singh *et al*., 2009)

Laboratory Analysis

Proximate Composition

Maize starch samples obtained at different malting periods were analyzed for moisture, ash, protein, fat, and carbohydrate according to the method described by AOAC, (2010).

Amylose content determination

Amylose contents were determined according to the method of Udachan *et al.,* (2012). 0.1g of the starch samples and 70% amylose standard were weighed into different test tubes then 1ml of 95% ethanol and 9ml of 1M NaOH were added and then mixed on a vortex mixer. The test tubes were heated in a boiling water bath for 10 min to gelatinize the starch after which they were allowed to cool very well (it should contain 10ml extract). 1ml each was taken from the extracts into another test tube and was made up to 10ml with 9ml distilled water. From this 10ml diluent, 0.5ml was taken into another test tube and 0.1ml Acetic acid solution and 0.2ml Iodine solution was then added and made up to 10ml with 9.2ml of distilled water. It was left to stand for 20mins for colour development into dark blue complex. Test tubes were vortex and the absorbance was read on the spectrophotometer (Spectrumlab 22pc) at 620nm.

Calculation

$$\%\boldsymbol{Amylose} = \frac{\%\boldsymbol{Amylose\ of\ standard} \times \boldsymbol{Absorbance\ of\ sample} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \boldsymbol{eq.1}}{\boldsymbol{Absorbance\ of\ standard}}$$

Functional properties

Swelling and solubility Profile

The swelling power and solubility profile were determined according to the method of Adebowale *et al.,* (2009). Starch sample (5g) was weighed into a pre-weighed centrifuge tube, and 20ml of distilled water added and thoroughly shaken on a vortex. It was then heated to temperatures of 50 ^{0}C, 60 ^{0}C, 70 ^{0}C and 80 ^{0}C for 30 min in a water bath (HH-4, Techmel and Techmel. USA). The samples were centrifuged at 3000rpm for 20minutes. The supernatant was decanted carefully and residue weighed for swelling power determination.

The supernatant decanted was dried to a constant weight at 110 ^{0}C in hot air oven (TT 9053A Techmel and Techmel USA).. The residue obtained after drying the supernatant represented the amount of starch solubilized in water.

Calculation

$$\boldsymbol{Swelling\ power = \frac{weight\ of\ sediment}{Sample\ weight - weight\ of\ soluble} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eq.2}$$

$$\boldsymbol{\%Solubility = \frac{weight\ of\ soluble}{weight\ of\ sample} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eq.3}$$

Water absorption capacity

The water absorption capacities of the starches were determined according to the method of Claver *et al*, (2010). Distilled water (10ml) was added to 1g of sample, and the mixture was mixed thoroughly using a vortex mixer for 30 s and centrifuge at 4000 rpm for 10 min. The mass of water absorbed was expressed as g/g starch on a dry weight basis.

Hydration capacity

The hydration capacity of the starches was determined according to the method of Singh and Sandhu (2007). A suspension of 5g starch 75ml of distilled water was agitated for 1hr and centrifuge (3000rpm) for 10 min. The supernatant was decanted and the wet starch was drained for 10 min. The wet starch was then weighed.

Calculation

$$\boldsymbol{Water\ Binding\ Capacity\ (WBC)\% = \frac{Grams\ bound\ by\ water}{Sample\ weight} \times 100 \ldots\ldots\ldots\ldots eq.4}$$

Bulk density

Bulk density of the starch was determined according to the method of Musa *et al*, (2008). Starch (30g) was weighed into a 25ml measuring cylinder and the volume occupied was measured and recorded.

Calculation

$$\boldsymbol{Bulk\ density\left(\frac{g}{ml}\right) = \frac{weight\ of\ sample}{Volume\ occupied\ by\ sample} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eq.5}$$

Tapped density

Tapped density of the starch was determined according to the method of Musa *et al*, (2008). Starch (30g) was weighed into a 25ml measuring cylinder and was tapped 50 times. The volume occupied after tapping was then recorded.

Calculation

$$\boldsymbol{Tapped\ density\left(\frac{g}{ml}\right) = \frac{weight\ of\ sample}{volume\ occupied\ by\ sample} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eq.6}$$

Carr index

The flowability of the samples was determined by calculating the Carr's index according to the method of Musa *et al,* (2008). The difference between the tapped and bulk density divided by the tapped density was calculated and ratio expressed as percentage.

Calculation

$$\boldsymbol{Carr\ index}(\%) = \frac{\boldsymbol{tapped\ density - bulk\ density}}{\boldsymbol{tapped\ density}} \times \mathbf{100} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \boldsymbol{eq.7}$$

Statistical Analysis

Data obtained were subjected to analysis of variance (ANOVA) using Statistical software SAS (2009) for Microsoft Windows. The means were compared by using the Duncan Multiple Range Test (DMRT) and $p < 0.05$ was applied to establish significant difference.

RESULTS AND DISCUSSION

Effect of Malting Days on the Proximate Composition of Maize Starch

The results of the effect of malting days on the proximate composition of maize starch is presented in Table 1 The moisture content of the maize starches ranged between 13.33% and 12.16% for maize sprouted for 3 and 7 days respectively. Maize starch sprouted for 3 days had the highest moisture content while the maize starch sprouted for 7 days had the lowest moisture content. There was significant ($p<0.05$) difference in the values obtained. The values were within the range reported by other researchers (Ijarotimi, 2012; Reihaneh and Jamuna, 1997). However, low moisture content of food samples is a desirable phenomenon, because it helps to reduce microbial activities of the food sample (Oyenuga, 1968). The protein content of the maize starches ranged between 4.21% and 4.4% for maize sprouted for 0 day, 3 days, 5 days, and 7 days respectively. Slight increase was observed and the values were not significantly ($p<0.05$) different from one another. The result agreed with the reports of other researchers that processing method such as sprouting helps to improve the nutritional quality of food products, especially in terms of protein content (Enujiugha *et al.,* 2003; Fasasi, 2009).

The ash content for maize starches ranged between 0.28% and 0.42% for maize sprouted for 0 and 7 days respectively. The ash content of the starches increased as malting period increased although the values were not significantly ($p<0.05$) different. The ash content also followed the same trend with the protein content. Mbaeyi and Onweluzo, (2010) reported a decrease in the ash content of germinated sorghum flour. The fat content ranged between 3.71% and 2.17% for maize malted for 0 and 5 days respectively. There was decrease in fat content of the starch as the malting period increased, although the values were not significantly ($p<0.05$) different. This did not agree with the report of Mbaeyi and Onweluzo, (2010) who reported an increase in fat content of sprouted sorghum flour. The decrease in fat content may be due to the presence of free fatty acids reacting with other products of hydrolysis to form esters (Mbaeyi and Onweluzo, 2010), which might have been used for synthesis of new lipids during metabolic activities of micro flora in the substrates during sprouting.

The carbohydrate content of the starches ranged between 78.91% and 80.69% for maize sprouted for 0 and 5 days respectively. Maize starch malted for 5 days had the highest carbohydrate content while the starch of the unmalted maize had the lowest carbohydrate content, although all the values were not significantly ($p<0.05$) different.

Effect of Malting Periods on Amylose and Amylopectin of Maize starch.

The results of the effect of malting period on amylose and amylopectin of maize starch are presented in Table 2. The amylose content of maize starches ranged between 22.81% and 25.49% for maize malted for 0 and 7 days respectively. Mbaeyi and Onweluzo, (2010) reported a continuous increase in amylose content of malting period increasd in sorghum flour. This increase could be as a result of the breakdown of starch into simple sugars (amylose) by the amylolytic enzymes inherent in the seeds during sprouting.

The amylopectin of maize starches ranged between 77.19% and 74.51% for maize malted for 0 and 7 days respectively. The starch that has the lowest amylose content had the highest amylopectin and vice versa.

Effect of Malting Period on the Functional Properties of Maize Starch

The results of the effect of malting period on the functional properties of maize starch are presented in Table 3. The bulk density values of the starch ranged between 0.30g/ml and 0.25g/ml for maize malted for 3 and 7 days respectively. The starch from maize malted for 3 days had the highest bulk density although all the values were not significantly ($p<0.05$) different. The bulk density obtained in this report was also lower than 0.62 g/cm^3 reported for tigernut flour, 0.54 g/cm^3 for African breadfruit kernel flour and 0.71 g/cm^3 reported for wheat flour (Akubor and Badifu, 2004; Oladele and Aina, 2007). The bulk density implies that less quantity of the food samples would be packaged in constant volume thereby ensuring an economical packaging. The tapped density of the maize starches ranged between 0.38g/ml and 0.31g/ml for maize malted for 3 and 7 days respectively. Although, starch from maize sprouted for 3 days had the highest tapped density, all the values are not significantly ($p<0.05$) different. The tapped densities would ensure that more quantity of food samples is packaged, but less economical (Osundahunsi and Aworh, 2002).The Carr's index of maize starches ranged between 23.53% and 17.65% for maize malted for 0 and 7 days. The Carr index is a function of the flowability of the product, the lower the value, the higher the flowability.

The water absorption capacities of maize starches ranged between 96.22% and 100.51% for maize malted for 3 and 7 days respectively. The water absorption values of the starches were lower than the values of germinated wheat flour (315%) reported by Ijarotimi (2012). Water absorption capacity of starch is an index of the maximum amount of water that the starch can absorb (Marero *et al.*, 1988). Studies have shown that the microbial activities of food product with low water absorption capacity can be reduced (Giami and Bekeham, 1992) hence; the shelf life of such product can be extended. Water absorption capacity dictates the water holding power of starch i.e. when used in soups and thickeners (Udachan *et al.*, 2012). The hydration capacity values of the maize starches ranged between 96.69% and 132.47% for maize malted for 0 and 7 days respectively. The hydration capacities of the starches increased as the malting days increased. Maize starches sprouted for 5 days and 7 days were not ($p<0.05$) significantly different.

The results of the effect of malting days on the swelling profile of maize starch at different temperatures are graphically represented in Figure 2. The values obtained from maize malted for different days at the same temperature did not follow a particular trend; the swelling values were higher when the temperature increased, because at high temperature the mobility of the water molecules rises, resulting in an increased absorption of water (Ross, 1995). The values of the swelling powers of the starches at different temperatures were all significantly ($p<0.05$)

different for the different days. The solubility index of the starches are represented graphically in figure 3. The values of the solubility index of the starches at different temperatures were all significantly ($p<0.05$) different for the different days. The pattern of solubility index of the starches was similar to that of the swelling power; at higher temperature the solubility increased, This could be caused by amylose solubilization during starch gelatinization. When starch dispersions are heated, the swelling of granules and starch polymer solubilization also occur. Starch solubility is considered as an indicator of the degree of dispersion of molecule of starch granules after cooking (Phattanakulkaewmorie *et al.*, 2011). Increase in solubility correlates with the study of Mendez-Montealvo *et al.*, (2007) who reported an increase in the solubility of nixtamalized maize starch.

Table 1: Effect of sprouting periods on the proximate composition of maize starch

MALTING PERIOD	MOISTURE	PROTEIN	ASH	FAT	CARBOHYDARTE
	(%)	(%)	(%)	(%)	(%)
DAY 0	12.89^{b}	4.21^{a}	0.28^{a}	3.71^{a}	78.92^{a}
DAY 3	13.33^{a}	4.38^{a}	0.29^{a}	2.61^{a}	79.40^{c}
DAY 5	12.41^{c}	4.39^{a}	0.35^{a}	2.17^{a}	80.69^{a}
DAY 7	12.16^{d}	4.47^{a}	0.42^{a}	2.53^{a}	80.42^{a}

Values are mean of duplicate samples. Values with the same superscript in the same column are not significantly ($p<0.05$) different.

Table 2: Effect of Sprouting period on the amylose and amylopectin of maize starch

MALTING PERIOD	AMYLOSE (%)	AMYLOPECTIN (%)
DAY 0	22.81[c]	77.19[a]
DAY 3	24.99[a]	75.01[c]
DAY 5	23.83[b]	76.17[b]
DAY 7	25.49[a]	74.51[c]

Values are mean of duplicate samples. Values with the same subscript in the same column are not significantly ($p<0.05$) different.

Table 3: Effect of sprouting period on the functional properties of maize starch

MALTING PERIOD	Bulk Density (g/ml)	Tapped Density (g/ml)	Carr Index(%)	Water Absorption Capacity (%)	Water Binding Capacity (%)
DAY 0	0.26[a]	0.34[a]	23.44[a]	96.23[a]	96.69[c]
DAY 3	0.30[a]	0.38[a]	21.11[a]	96.22[a]	107.75[b]
DAY 5	0.29[a]	0.37[a]	21.54[a]	98.95[a]	128.29[a]
DAY 7	0.25[a]	0.31[a]	18.84[a]	100.51[a]	132.47[a]

Values are mean of duplicate samples. Values with the same superscript in the same column are not significantly ($p<0.05$) different.

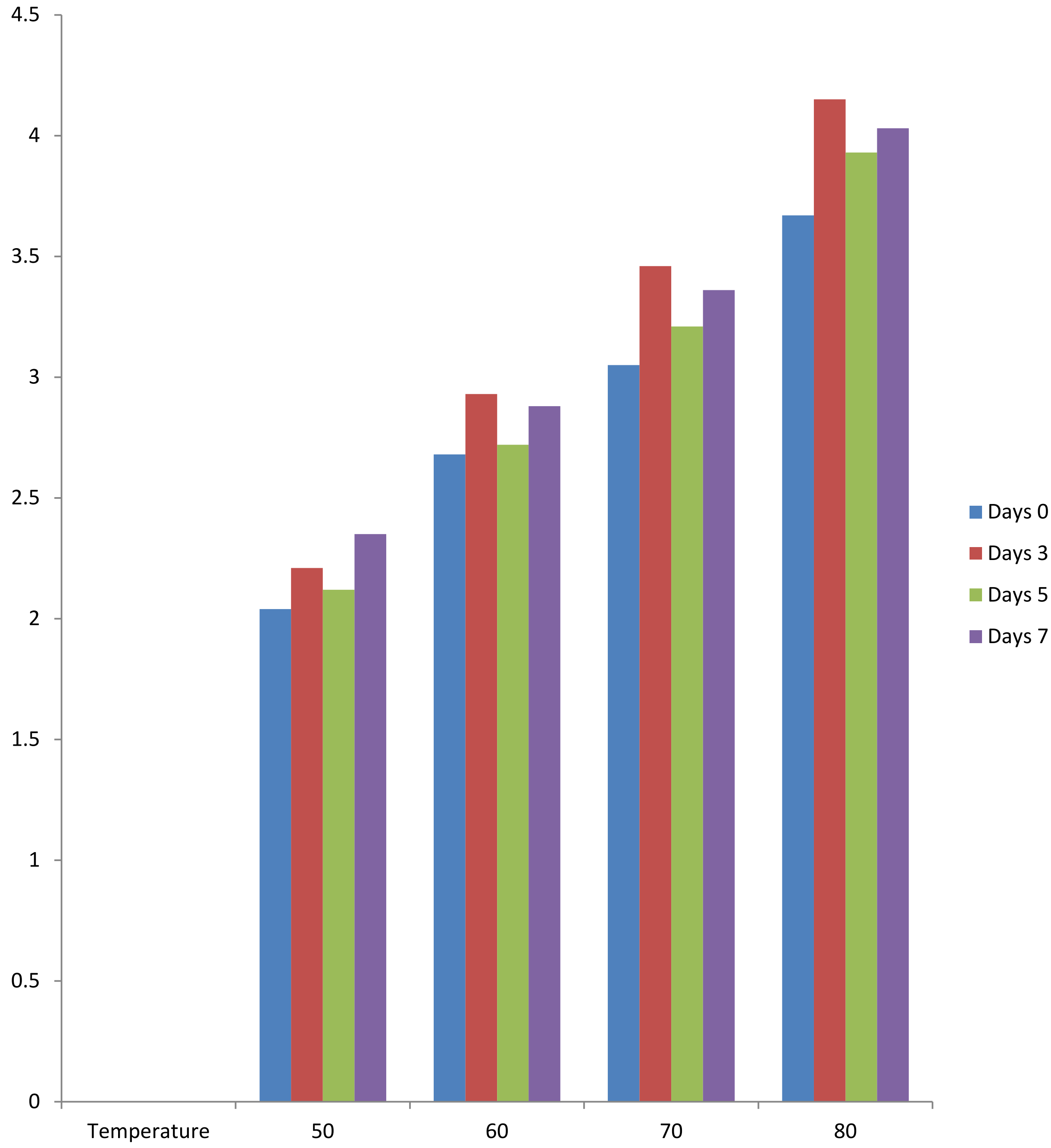

Fig. 2: Effect of malting period on the swelling power of maize starch.

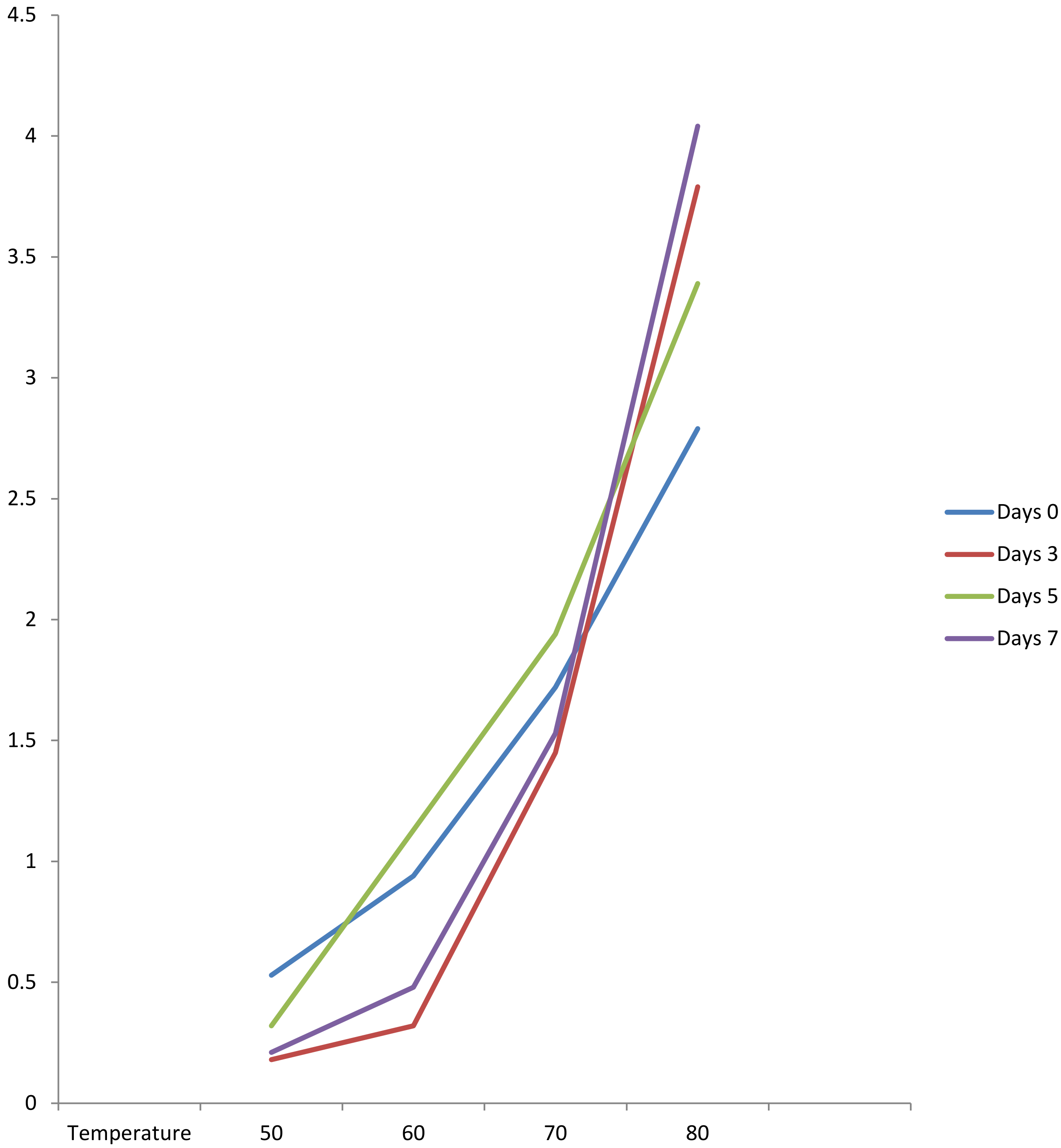

Fig. 3: Effect of malting period on the solubility index of maize starch.

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