International Research Journal of Agricultural Science and Soil Science (ISSN: 2251-0044) Vol. 1(7) pp. 254-260 September 2011
Available online http://www.interesjournals.org/IRJAS

Full Length Research Paper

Effect of heat moisture treatment on physicochemical and pasting properties of starch extracted from eleven sweet potato varieties

[1, 2]M.Tsakama*, [2]A.M. Mwangwela, [2]T.A. Manani and [3]N.M. Mahungu

[1]University of Malawi, Polytechnic, P/Bag 303, Blantyre 3, Malawi
[2]University of Malawi, Bunda College of Agriculture, P.O Box 219, Lilongwe, Malawi
[3]IITA/SARRNET, P.O Box 30258, Lilongwe 3, Malawi

Accepted 09 August, 2011

Starch separated from eleven sweet potato varieties was subjected to heat moisture treatment (HMT) at 30% moisture and 110˚C for 3 hours. Following HMT, there were no significant changes in physicochemical properties of the starches. This was attributed to limited moisture content (30%) to influence hydration that could consequently alter granule morphology. Further, chemical parameters such as amylose content, pH and phosphorus were not affected because HMT is a physical treatment. In contrast, HMT caused changes in the packing arrangement of the polymer chains leading to enhanced intragranular binding. Alteration of the internal organisation of the granules caused significant changes in pasting properties of the starches such as pasting time, pasting temperature, peak viscosity, hot paste viscosity, cold paste viscosity, breakdown, set back and stability ratios. The findings provide evidence that functionality of sweet potato starch can be altered to suit a particular industrial need.

Keywords: Heat-moisture treatment, sweet potato starch, pasting.

INTRODUCTION

Starch is the principle food reserve polysaccharide in plants with great economic and nutritional importance. Starch is widely used in food industry as a thickening, stablising and gelling agent, hence an excellent ingredient for the manufacture of various food products (Wurtzburg, 1999; Slattery, Kavakli and Okita, 2000). The growing demand for starch in food industry has created interest for new sources of starch (Adewabole, Owolabi, Olayinka and Lawal, 2005). Sweet potato is one such crop that has shown potential as a source of starch.

The utility of sweet potato starch is primarily determined by its physicochemical properties which are affected by amylose content, molecular structure, granule size and shape. Pasting properties also influence the quality of food processing materials and industrial products. Sweetpotato starch with slower retrogradation is suitable for confectioneries like gelatinized cakes. Starch with faster retrogradation is ideal for starch noodles. Improvement of retrogradation is expected to spread the application of sweetpotato starch to such foodstuffs (Jacobs and Delcour, 1998).

Sweet potato starch, like other root crop starches such as cassava, potato and arrow root, is considered more free swelling and exhibits a type A Brabender amylograph. Type A amylograph is characterised by a high pasting peak followed by rapid and major thinning on cooling (Collado, Mabesa, Oates and Corke, 2001). These characteristics limit the utilisation of sweet potato starch in food industry especially in products that require starches with faster retrogradation rates like starch noodles.

These requirements could be met by modifying native starch using chemical or physical methods. Of interest are the physical (heat-treatment) methods because chemical reagents are not required to impart a modifying effect (Jacobs and Delcour, 1998) and therefore, rela-

---

*Corresponding author email: mtsakama@gmail.com

tively cheaper to produce. There are two types of heat treatment processes that cause physical modification. These are heat-moisture treatment (HMT) and annealing. HMT involves heating starch at temperatures above its gelatinization point (70-130°C) for one to several hours but with insufficient moisture (15-35%) to cause gelatinization. In annealing, slurry of granular starch is heated at a temperature below its gelatinization point for prolonged periods of time after which the starch shows an enhanced viscosity profile (Jacobs and Delcour, 1998). The use of these processes has the potential of giving sweetpotato starch desired physical properties for application in the manufacture of various starch based products. HMT is preferable to annealing because it is simple, environmentally safe and requires less time.

Hydrothermal treatment of starch has proved to increase gelatinization temperature (Donovan, Lorenz and Kulp, 1983; Lim, Chung and Chung, 2001), restrict swelling and increase starch paste stability (Hoover and Vasanthan, 1994; Jacobs, Eerlingen, Clauwaert and Delcour, 1995). Starch gel structure was altered and gel hardness increased following HMT (Chung, Moon and Chun, 2000).

In Malawi, commercial utilization of sweet potato for industrial raw materials like flour and starch is non-existent although it would add value to the produce, increase revenue for farmers and processors and create new market opportunities for new products. The objective of this study was to determine the impact of HMT on the physiochemical and pasting properties of starch extracted from eleven sweet potato varieties.

MATERIALS AND METHODS

Starch isolation

Starch isolation was carried out based on the method of Brabet, Reynoso, Dufour, Mestres, Arredondo and Scott (1999). Freshly harvested sweet potato tubers from eleven varieties (Kenya, Mugamba, Zondeni, Salera, Semusa, Lunyangwa, LU96/274, LU96/303, LU96/304, LU96/334 and LU96/374) were thoroughly washed, peeled and macerated in a heavy duty grater into a bowl of water. The resultant suspension was filtered through a muslin cloth. The residue was then re-suspended in tap water (1:2 v/v) and filtered in the same way. The two filtrates were pooled and passed through a 250 µm sieve. Starch was allowed to settle for 3 hours at room temperature (20-24°C) and the supernatant was discarded. The starch was then re-suspended in tap water and filtered through a 75 µm sieve and left to settle for 2 hours. This step was repeated three times replacing tap water with deionised water for the two last washings. Recovered starch was dried in a DV 600 hot air oven (Yamato, Japan) at 40-45°C for 24 hours. Dried starch was then ground in a laboratory blender (Waring, USA) to pass through a 250 µm sieve and stored in sealed polyethylene (Ziploc) bags at 6°C.

Starch modification

Sweet potato starch was adjusted to 30% moisture by addition of distilled water and equilibrated at 5°C overnight (refrigerated condition). The moisture adjusted samples were placed in foil covered baking pans and heated in a DV600 oven (Yamato, Japan) for 3 hours at 110°C. Modified starch samples were then cooled to room temperature and dried at 50˚C in an oven, equilibrated for 4 hours and sealed in polyethylene bags (Collado et al., 2001).

Physicochemical properties of starches

Moisture content of the starches was determined by drying 2 g of sample in a DV 600 box oven (Yamato, Japan) for 1 hour at 130°C. pH was determined using a 2500 series pH meter (Oakton, Singapore) after standardising with buffer solutions of pH4 and pH9. Determination of phosphorus also followed the standard titrimetric method (AOAC, 2002).

Starch granule morphology

Starch granule morphology was studied by staining 0.01% granule suspensions (1 g of starch into 100 ml distilled water) with 0.1% iodine solution. Granule size was measured and photographed using an SZ6045 zoom stereo microscope (Olympus Optical Co, Japan) fitted with a calibrated eyepiece to calculate the average and range of the granules (Umerie and Ezenzo, 2000).

Amylose content

Amylose content of the starch was measured by complex formation according to a method described by Chrastil (1987). Absorbance of the developed colour was read at 620 nm using a Spectronic 601 spectrophotometer (Milton Roy Co, USA).

Starch pasting properties

Starch pasting properties were determined by subjecting a starch suspension of 3 g starch in 25 ml distilled water to a controlled heating and cooling cycle under constant shear using a Rapid Visco Analyser – 3 series (Newport Scientific Pvt Ltd, Australia). Pasting parameters were measured over time. These parameters included onset of pasting to peak viscosity (P_{time}); temperature at which

Table 1. Effect of HMT on physicochemical properties of starch extracted from eleven sweet potato varieties.

Variety	Treatment	Moisture (%)	pH	Phosphorus (mg/g	Amylose (%)	Granule size (µm)
Lunyangwa	Native	7.60 ± 0.18^{a}	4.57 ± 0.06^{a}	0.76 ± 0.05^{a}	14.95 ± 2.09^{a}	12.13 ± 0.32^{a}
	Modified	7.16 ± 0.13^{b}	4.56 ± 0.05^{a}	0.16 ± 0.002^{b}	14.76 ± 1.65^{a}	14.73 ± 0.70^{a}
Semusa	Native	12.40 ± 0.11^{a}	4.43 ± 0.06^{a}	0.17 ± 0.02^{a}	18.69 ± 1.96^{a}	13.63 ± 0.35^{a}
	Modified	11.21 ± 0.42^{b}	4.30 ± 0.03^{a}	0.16 ± 0.002^{a}	16.53 ± 2.45^{a}	14.40 ± 0.43^{a}
Salera	Native	10.20 ± 0.06^{a}	5.57 ± 0.06^{a}	0.09 ± 0.02^{a}	10.50 ± 0.55^{a}	15.80 ± 0.89^{a}
	Modified	10.66 ± 0.32^{b}	5.60 ± 0.00^{a}	0.10 ± 0.002^{a}	9.92 ± 0.42^{a}	14.13 ± 0.85^{a}
Zondeni	Native	11.40 ± 0.02^{a}	5.37 ± 0.12^{a}	0.03 ± 0.01^{a}	15.97 ± 0.46^{a}	12.77 ± 0.25^{a}
	Modified	10.58 ± 0.23^{b}	5.55 ± 0.20^{a}	0.04 ± 0.001^{a}	14.56 ± 1.30^{a}	12.70 ± 0.95^{a}
Kenya	Native	11.50 ± 0.08^{a}	4.87 ± 0.06^{a}	0.11 ± 0.01^{a}	11.85 ± 1.26^{a}	14.43 ± 0.60^{a}
	Modified	10.09 ± 0.07^{b}	4.67 ± 0.20^{a}	0.10 ± 0.001^{a}	10.50 ± 0.65^{a}	14.63 ± 0.77^{a}
Mugamba	Native	10.60 ± 0.29^{a}	5.30 ± 0.36^{a}	0.13 ± 0.03^{a}	18.63 ± 2.96^{a}	11.57 ± 0.83^{a}
	Modified	9.27 ± 0.16^{b}	5.20 ± 0.20^{a}	0.12 ± 0.001^{a}	18.10 ± 2.46^{a}	11.17 ± 0.25^{a}
LU96/274	Native	8.00 ± 0.09^{a}	5.50 ± 0.30^{a}	0.16 ± 0.02^{a}	14.96 ± 2.32^{a}	14.47 ± 0.70^{a}
	Modified	8.22 ± 0.19^{a}	5.43 ± 0.00^{a}	0.15 ± 0.01^{a}	14.16 ± 1.70^{a}	13.23 ± 0.55^{a}
LU96/303	Native	8.20 ± 0.06^{a}	4.57 ± 0.15^{a}	0.12 ± 0.06^{a}	12.67 ± 1.73^{a}	11.70 ± 0.82^{a}
	Modified	10.61 ± 0.16^{b}	4.76 ± 0.05^{a}	0.11 ± 0.001^{a}	11.70 ± 1.05^{a}	12.26 ± 0.66^{a}
LU96/304	Native	7.90 ± 0.14^{a}	5.57 ± 0.15^{a}	0.11 ± 0.02^{a}	11.92 ± 0.75^{a}	15.77 ± 0.59^{a}
	Modified	10.57 ± 0.32^{b}	5.50 ± 0.01^{a}	0.11 ± 0.02^{b}	10.60 ± 0.95^{a}	14.83 ± 0.90^{a}
LU96/334	Native	8.60 ± 0.23^{a}	4.57 ± 0.21^{a}	0.08 ± 0.01^{a}	13.78 ± 1.47^{a}	13.78 ± 0.21^{a}
	Modified	10.57 ± 0.26^{b}	4.60 ± 0.00^{a}	0.07 ± 0.005^{a}	11.80 ± 2.25^{a}	14.33 ± 0.58^{a}
LU96/374	Native	6.83 ± 0.33^{a}	4.33 ± 0.23^{a}	0.13 ± 0.06^{a}	12.03 ± 1.77^{a}	11.83 ± 0.70^{a}
	Modified	11.08 ± 0.07^{b}	4.23 ± 0.53^{a}	0.12 ± 0.005^{a}	12.10 ± 0.43^{a}	2.86 ± 0.41^{a}

Means followed by the same superscript in a column within each variety are not significantly different ($p\leq0.05$).

peak viscosity was reached (P_{temp}); peak viscosity (PV); viscosity at the end of the holding time at 95°C or hot paste viscosity (HPV) and viscosity at the end of the holding time at 50°C or cold paste viscosity (CPV). From these parameters, breakdown and stability ratio and were calculated.

Statistical analysis

Statistical Package for Social Scientists (SPSS, version 15.0) was used for statistical analysis. tested for significance using analysis of variance techniques. Duncan's Multiple Range Test was used as a post hoc procedure when the analysis of variance indicated significant differences in the means. A significance level of $P < 0.05$ was used throughout the study.

RESULTS AND DISCUSSION

Effect of Heat Moisture Treatment on Starch Physicochemical properties

Effect of HMT on starch physicochemical characteristics was assessed by conducting an independent samples t-test (Table 1). It was observed that there were no significant differences in granule size, amylose content, pH, moisture content and phosphorus. These results were in line with previous findings of Singh et al (2005). Other researchers, working on cocoyam, cassava, oat and potato starches, also found no changes in the physicochemical properties of these starches after HMT. This was because there were no chemical reactions because HMT is a physical treatment

Table 2. Effect of HMT on pasting properties of starch extracted from eleven sweet potato varieties

Variety	Treatment	P_{time}^{w} (Min)	P_{temp}^{w} (˚C)	PV^{w} $(cP)^{x}$	HPV^{w} $(cP)^{x}$	CPV^{w} $(cP)^{x}$	$Breakdown^{w}$ $(cP)^{x}$
Lunyangwa	Native	5.17 ± 0.01^{a}	73.63 ± 0.32^{a}	2179.67 ± 9.04^{a}	1631.33 ± 28.59^{a}	2461.67 ± 10.69^{a}	548.33 ± 11.28^{a}
	Modified	6.72 ± 0.1^{b}	83.63 ± 0.26^{b}	1144.21 ± 4.61^{b}	1137.33 ± 2.72^{b}	1489.67 ± 3.18^{b}	6.67 ± 0.17^{b}
Semusa	Native	5.02 ± 0.03^{a}	75.88 ± 0.03^{a}	2080.33 ± 2.08^{a}	1572.67 ± 6.50^{a}	2444.67 ± 4.51^{a}	507.66 ± 2.96^{a}
	Modified	6.24 ± 0.06^{b}	84.86 ± 0.03^{b}	1070.00 ± 1.15^{b}	1060.33 ± 0.33^{b}	1416.00 ± 1.51^{b}	9.67 ± 0.20^{b}
Salera	Native	5.03 ± 0.03^{a}	74.29 ± 0.09^{a}	2179.00 ± 2.00^{a}	1692.00 ± 3.06^{a}	2664.00 ± 2.00^{a}	486.34 ± 2.67^{a}
	Modified	7.40 ± 0.01^{b}	83.15 ± 0.03^{b}	1059.00 ± 0.57^{b}	1021.01 ± 1.20^{b}	1374.00 ± 1.14^{b}	38.00 ± 1.21^{b}
Zondeni	Native	4.98 ± 0.03^{a}	73.50 ± 0.56^{a}	2115.00 ± 8.79^{a}	1541.33 ± 8.04^{a}	2639.67 ± 9.65^{a}	573.67 ± 4.48^{a}
	Modified	6.26 ± 0.08^{b}	82.43 ± 0.06^{b}	1333.33 ± 4.48^{b}	1300.67 ± 1.76^{b}	1830.67 ± 8.96^{b}	32.67 ± 1.37^{b}
Kenya	Native	5.16 ± 0.04^{a}	73.40 ± 0.06^{a}	1947.00 ± 9.00^{a}	1624.33 ± 5.86^{a}	2690.33 ± 7.09^{a}	322.67 ± 3.45^{a}
	Modified	8.41 ± 0.10^{b}	84.70 ± 0.04^{b}	1205.67 ± 5.78^{b}	1186.33 ± 6.06^{b}	1452.00 ± 6.52^{b}	19.33 ± 0.33^{b}
Mugamba	Native	5.40 ± 0.14^{a}	75.10 ± 0.30^{a}	1950.00 ± 9.00^{a}	1728.33 ± 9.93^{a}	2646.33 ± 42.92^{a}	221.67 ± 2.34^{a}
	Modified	7.24 ± 0.09^{b}	83.90 ± 0.17^{b}	990.67 ± 5.61^{b}	979.33 ± 5.33^{b}	1238.33 ± 5.48^{b}	11.34 ± 0.67^{b}
LU96/274	Native	4.14 ± 0.06^{a}	73.57 ± 0.08^{a}	2596.67 ± 7.05^{a}	1707.33 ± 16.04^{a}	2762.00 ± 22.00^{a}	899.33 ± 5.20^{a}
	Modified	7.01 ± 0.02^{b}	83.33 ± 0.74^{b}	1176.67 ± 4.41^{b}	1171.00 ± 3.60^{b}	1628.00 ± 6.11^{b}	5.67 ± 0.88^{b}
LU96/303	Native	4.14 ± 0.09^{a}	74.90 ± 0.20^{a}	2370.00 ± 8.94^{a}	1672.67 ± 9.45^{a}	2585.00 ± 25.00^{a}	697.33 ± 7.68^{a}
	Modified	6.93 ± 0.04^{b}	84.75 ± 0.08^{b}	1131.00 ± 6.35^{b}	1125.67 ± 6.11^{b}	1532.67 ± 6.90^{b}	5.33 ± 0.48^{b}
LU96/304	Native	5.04 ± 0.04^{a}	74.20 ± 0.40^{a}	2404.00 ± 26.23^{a}	2049.33 ± 29.28^{a}	3261.67 ± 23.25^{a}	354.67 ± 4.67^{a}
	Modified	7.61 ± 0.02^{b}	83.97 ± 0.14^{b}	1293.00 ± 16.86^{b}	1266.00 ± 17.01^{b}	1652.00 ± 19.50^{b}	27.00 ± 5.00^{b}
LU96/334	Native	4.12 ± 0.03^{a}	75.07 ± 0.18^{a}	2130.67 ± 34.02^{a}	1496.33 ± 6.51^{a}	2304.00 ± 22.27^{a}	634.33 ± 6.23^{a}
	Modified	6.80 ± 0.17^{b}	83.45 ± 0.09^{b}	1136.33 ± 7.83^{b}	1107.33 ± 5.81^{b}	1529.67 ± 7.31^{b}	29.00 ± 2.51^{b}
LU96/374	Native	5.04 ± 0.04^{a}	74.17 ± 0.15^{a}	2111.67 ± 10.41^{a}	1654.64 ± 13.32^{a}	2734.00 ± 14.00^{a}	457.00 ± 4.04^{a}
	Modified	7.75 ± 0.05^{b}	83.76 ± 0.10^{b}	1015.00 ± 2.88^{b}	995.00 ± 3.60^{b}	1251.33 ± 3.52^{b}	20.00 ± 1.15^{b}

Means followed by the same superscript in a column within each variety are not significantly different ($p \leq 0.05$).
^{w}Starch pasting properties: P_{time} = Time to reach peak; P_{temp} = Pasting temperature; PV = Peak viscosity; HPV = Hot paste viscosity; CPV = Cold paste viscosity ^{x}Centipoise

(Hoover and Vasanthan, 1994; Lawal, 2005).

Effect of Heat Moisture Treatment on Starch Pasting Properties

Pasting properties of the modified starches from the eleven varieties varied (Table 2) and showed significant differences ($p \leq 0.05$) between the two treatments. A change was observed in the pasting profile of the starches exposed to heat-moisture treatment from type A (Figures 1A) to type C (Figure 1B).

Type C profile is characterised by no pasting peak, but rather a high viscosity which remains constant or increases during cooling (Jacobs and Delcour, 1998; Chen et al., 2003; Purwani, Widaningrum, Thahir and Muslic, 2006). This change was probably due to alteration of the amorphous region of the granules. Heat-moisture treatment has been found to cause a change in the packing arrangement of the polymer chains and also causes partial crystal melting in hydrothermally treated starches (Jacobs, Eerlingen, Clauwaert, and Delcour, 1995; Shin, Kim, Ha, Lee, and Moon, 2005).

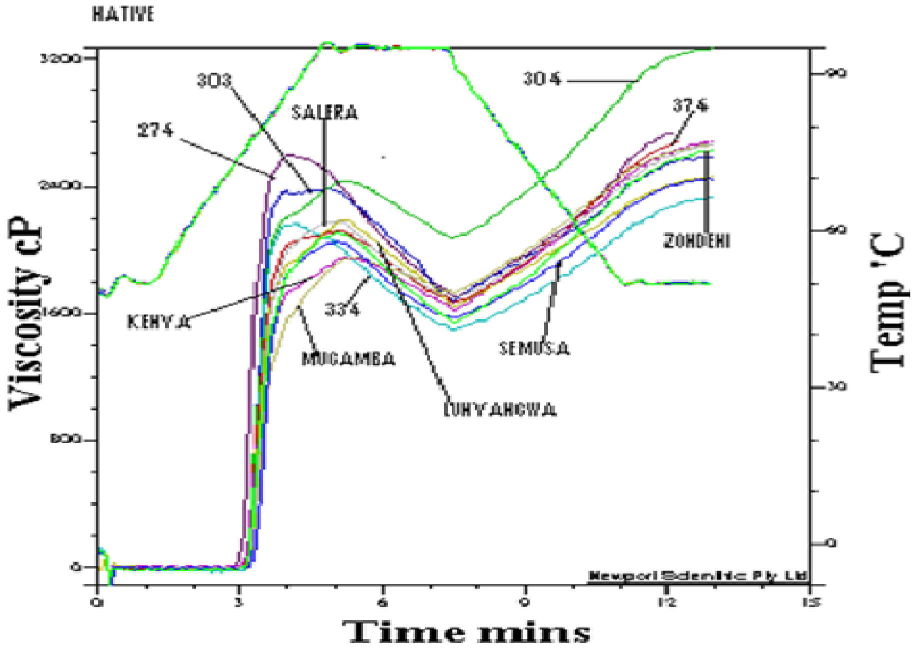

Figure 1A. RVA viscosity profiles of native sweet potato starch pastes

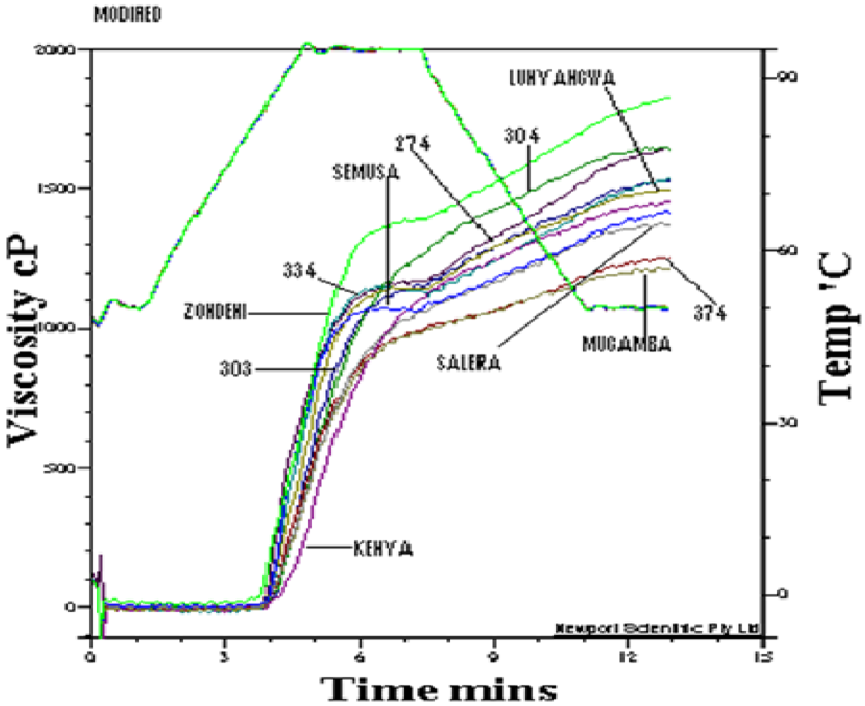

Figure 1B. RVA viscosity profiles of HMT sweet potato starch pastes

Mean pasting temperature and time significantly increased ($p \leq 0.05$) after heat-moisture treatment possibly because of the increase in crystallinity (Table 2). Hydrothermal treatment has been established to enhance

Table 3. Effect of HMT on stability and setback ratio of starch extracted from eleven sweet potato varieties

	Treatment	**Stability ratio**	**Setback ratio**
Lunyangwa	Native	0.75±0.01^{a}	1.51±0.02^{a}
	Modified	0.99±0.03^{b}	1.31±0.01^{b}
Semusa	Native	0.75±0.01^{a}	1.56±0.01^{a}
	Modified	0.99±0.02^{b}	1.33±0.03^{b}
Salera	Native	0.78±0.00^{a}	1.57±0.00^{a}
	Modified	0.96±0.03^{b}	1.34±0.01^{b}
Zondeni	Native	0.73±0.00^{a}	1.71±0.04^{a}
	Modified	0.97±0.03^{b}	1.40±0.08^{b}
Kenya	Native	0.83±0.01^{a}	1.65±0.01^{a}
	Modified	0.98±0.01^{b}	1.22±0.06^{b}
Mugamba	Native	0.89±0.01^{a}	1.53±0.02^{a}
	Modified	0.99±0.01^{b}	1.26±0.03^{b}
LU96/274	Native	0.66±0.01^{a}	1.62±0.17^{a}
	Modified	0.99±0.03^{b}	1.39±0.07^{b}
LU96/303	Native	0.71±0.01^{a}	1.54±0.03^{a}
	Modified	0.97±0.05^{b}	1.36±0.12^{b}
LU96/304	Native	0.85±0.00^{a}	1.59±0.02^{a}
	Modified	0.98±0.03^{b}	1.31±0.06^{b}
LU96/334	Native	0.70±0.01^{a}	1.54±0.01^{a}
	Modified	0.97±0.03^{b}	1.38±0.04^{b}
LU96/374	Native	0.78±0.01^{a}	1.65±0.01^{a}
	Modified	0.98±0.05^{b}	1.26±0.03^{b}

Means followed by the same superscript in a column are not significantly different at $p \leq 0.05$

perfection of crystallites (Lawal, 2005). This was possibly initiated by incipient swelling and the resulting mobility of the amorphous α-glucans which facilitated ordering of the amylose double helices. It is therefore reasonable, that following HMT, starch granules required more heat and time before structural disintegration and paste formation occurred (Lawal, 2005). Reduction in PV, HPV and CPV following modification was assumed to be a result of the reorganization within the granules of the modified starches. This led to low restricted swelling capacity and only a small amount of amylose was able to leach into the medium to elevate its viscosity (Harmdok and Noomhorm, 2007).

Breakdown values were significantly lower ($p \leq 0.05$) for HMT starches which is an indication that the granules were strong and resisted breakdown under shear and heat, a result also noted by Singh et al (2006). Low breakdown coupled with high viscosity is a desirable property of starch because its paste has a non-cohesive texture suitable for many food and industrial applications. It is speculated that HMT makes the granules resistant to deformation by strengthening the intragranular binding forces (Collado and Corke, 1999; Singh et al, 2006). The formation of a tightly packed array of swollen and deformed granules and the leaching of amylose can contribute to viscosity development in starch pastes during heating. Rigidity of granules consequently increases due to insufficient gelatinization leading to a higher viscosity of pastes because the rigid granules were resistant to shearing (Adebowale et al., 2005).

Stability ratio explains the resistance of a starch paste to viscosity breakdown as shear is applied. HMT starches showed significantly ($p \leq 0.05$) higher stability ratios (Table 3) because of the improved organisation within the starch granules. This organisation gave the starches a longer paste-peak time and hence swelled more gradually and thus, not as susceptible to mechanical damage (Wiesenborn et al., 1994). Setback ratio, which is an indication of starch retrogradation tendency after gelatinization, was significantly reduced ($p \leq 0.05$) following HMT. Enhancement of crystallinity after hydrothermal treatments limited starch swelling, structural disintegration and amount of amylose leaching into the medium. As such there was not enough reassociating of amylose molecules hence leading to reduced setback values (Table 3).

CONCLUSION

HMT (30% moisture, 110^{0}C for 3 hours) caused no significant changes in granule morphology, amylose content, pH, moisture and phosphorus contents. However, HMT had a dramatic influence on all the pasting properties, showing significant differences after modification. The pasting profile changed from type A to type C. There was a general increase in Ptime, Ptemp and stability ratio while PV, HPV CPV and BD significantly decreased. This was due to the changes in the packing arrangement of the polymer chains and ordering of the amylose double helices, leading to enhancement of intragranular binding. This leads to enhanced gel formation and strength, a desirable property in food products like starch-thickened sauces. Proper awareness of the potential of HMT could help in large-scale extraction and utilisation of sweet potato starch in Malawi.

RERERENCES

Adebowale K, Owolabi B, Olayinka O, Lawal O (2005). Effect of heat-moisture treatment and annealing on physicochemical properties of red sorghum starch. African J. Biotechnol. 4: 928-933.

AOAC International (2000). Official methods of analysis, 17th Ed. Association of Official Analytical Chemists, Gaithersburg, MD, USA.

Brabet C, Reynoso D, Dufour D, Mestres C, Arredondo J, Scott G (1999). Starch content and properties of 106 sweet potato clones from the world germplasm collection held at CIP, Peru. International Potato Centre. Lima, Peru.

Chen Z, Schols H, Voragen A (2003). Physicochemical properties of starches obtained from three varieties of Chinese sweet potatoes. J. Food Sci. 68: 431-437.

Chrastil J (1987). Improved calorimetric determination of amylose in starches or flours. Carbohydrate Research 159:154-158.

Chung K, Moon T, Chun L (2000). Influence of annealing on gel properties of mung bean starch. Cereal Chemistry 77 (5):567–571.

Collado L, Corke H (1996). Predicting the quality of sweetpotato starch noodles. In Howeler R. H, Oates C. and O'brien G. (Eds). Cassava, starch and starch derivatives. Proceedings of the International Symposium Nanning, Guangxi, China, pp11-15.

Donovan J, Lorenz K, Kulp K (1983). Differential scanning calorimetry of heat moisture treatment treated wheat and potato starches. Cereal Chemistry 60: 381–387.

Hoover R, Vasanthan T (1994). Effect of annealing on the physicochemical properties of wheat, oat, potato and lentil starches. J. Food Biochem. 17: 303-325.

Hoover R, Maunal H (1996). Effect of heat moisture treatment on the structure and physicochemical properties of legume starches. Food Res. Int. 29: 731–750.

Hormdork R, Noomhorm A (2006). Hydrothermal treatments of rice starch for improvement of rice noodle quality. LWT - Food Sci.Technol. 40: 1723 - 1731

Jacobs H, Eerlingen C, Clauwaert W, Delcour J (1995). Influence of annealing on pasting properties of starches from varying botanical sources. Cereal Chemistry 72:480-487.

Jacobs H, Delcour J (1998). Hydrothermal modification of granular starch with retention of the granular structure: J. Agric. Food Chem. 46:2895-2905.

Karim A, Toon L, Lee V, Ong W, Fazilah A, Noda T (2007). Effect of phosphorus content on the gelatinization and retrogradation of potato starch. J. Food Sci. 72: 132-138

Kaur A, Singh N, Ezekiel R, Guraya H (2007). Physicochemical, thermal and pasting properties of starches separated from different potato cultivars grown at different locations. Food Chem. 101: 643-651

Kim Y, Wiesenborn P (1996). Starch noodle quality as related to potato genotype. J. Food Sci. 61:248-252.

Lawal O (2005). Studies on the hydrothermal modification of new cocoyam (Xanthosona sagittifolium) starch. Int. J. Biol. Macromolecules 37: 268-277.

Lim S, Chang E, Chung H (2001). Thermal transition characteristics of heat moisture treated corn and potato starches. Carbohydrate Polymers 46: 107–115.

Purwani E, Widaningrum, Thahir R , Muslic (2006). Effect of heat moisture treatment of sago starch on its noodle quality. Indonesian J. Agric. Sci. 7: 8-14.

Shimelis E, Meaza M, Rakishit S (2006). Physicochemical properties, pasting behaviour and functional characteristics of flours and starches from improved bean (Phaseolus vulgaris L) varieties grown in East Africa. Agricultural Engineering International. CIGR e-journals, FP 05015. Vol III.

Shin S, Kim H, Ha, H, Lee, S, Moon T (2005). Effect of hydrothermal treatment on formation and structural characteristics of slowly digestible non-pasted granular sweet potato starch. Starch 57: 421-430.

Singh J, McCarthy O, Singh H (2006). Physicochemical and morphological characteristics of NewZealand Taewa (Maori potato) starches. Carbohydrate Polymers 64: 569-581.

Slattery C, Kavakli I, Okita T (2000). Engineering Starch for increased quantity and quality. Trends in Plant Sci. 5 (7): 291–298.

Stute R, Hellbronn S (1992). Hydrothermal modification of starches: the difference between annealing and heat / moisture treatment. Starch, 44:205-214.

Tian S, Rickard J, Blanshard J (1991). Physicochemical properties of sweet potato starch, J.Food Sci.Agric. 57: 459-491.

Umerie S, Ezeuzo H (2000). Physicochemical characterization and utilization of cyperus rotundus starch. Bioresource Technology 72:193-196

Wiesenborn D, Lorenzen J, Berglund P (1996). Suitability of edible bean and potato starches for starch noodles. Cereal Chemistry 73: 302-303.

Woolfe J (1992). Sweetpotato: An untapped food resource, Cambridge University Press. pp1 – 13; 366 – 372.

Wurzburg O (1999). Modified Starch. In: Stephen A.M, (Ed). Food Polysaccharides and items applications, Marcel Dekkers, New York.