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Research Article

Effect of Heat Moisture Treatment Conditions on Swelling Power and Water Soluble Index of Different Cultivars of Sweet Potato (*Ipomea batatas* (L). Lam) Starch

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A study was done to analyse the change in swelling power (SP) and the water soluble index (WSI) of native starches obtained from five different cultivars of sweet potatoes (swp 1 (Wariyapola red), swp 3 (Wariyapola white), swp 4 (Pallepola variety), swp 5 (Malaysian variety), and swp 7 (CARI 273)) commonly consumed in Sri Lanka. Extracted starch from fresh roots, two to three days after harvesting has been modified using 20%, 25%, and 30% moisture levels and heated at 85°C and 120°C for 6 hours and determined the SP and WSI. Results were subjected to general linear model, and analysis of variance (ANOVA) was carried out by using MINITAB version 14. Overall results showed a significantly high level ($P < 0.05$) of SP and WSI in all the cultivars of moisture—temperature treated starches than their native starch. Correlation analysis showed an effect on SP with the variation in the cultivar, temperature, and moisture; temperature combination and moisture alone had no significant effect. Significantly high levels of swelling power ($P > 0.05$) were observed in 20%—85°C, and 30%—120°C and the highest amount of swelling in the modified starch than its native form was observed in swp 7 cultivar. Results revealed a nonlinear relationship in the WSI with the cultivar type, moisture level, and the lower moisture—temperature combinations but higher temperature—moisture combinations had a significant effect. SP and WSI had a slight positive linear relationship according to analysis. Based on the results, a significantly high level of swelling and water solubility of native starches of different cultivars of sweet potatoes can be achieved by changing the moisture content to 30% and heating at 120°C for 6 hours.

1. Introduction

For a wide range of starch applications, native starches cannot be used due to inability to bring out the desired properties. Native starches can be modified to obtain the desired qualities by starch modification methods. Chemical modification of starch molecules is commonly used in achieving the desired properties. Also by using specific moisture and temperature conditions, some physicochemical properties of starch can be altered. There are more trends in the world for physical modification of starch which is used in food industrial applications as there is an increasing difficulty in obtaining regulatory approval of the new chemical reagents and higher levels of treatment as described by BeMiller [1]. Since most physical modifications involve only water and heat, these hydrothermal treatments are considered to be natural and safe materials by Jacobs and Delcour [2].

Two basic types of heat-moisture treatments are commonly employed in modifying the physicochemical properties of starch [3]. This involves the storage of starch at specific levels of moisture and heat for a specific period of time without causing a significant level of starch gelatinization. Treatment of starch with excess moisture is referred to as "annealing" [4–6], and the term "heat-moisture treatment" (HMT) is used when restricted levels of moisture are applied in the literature [7, 8]. These two types of physical modifications occur at temperatures above the glass transition temperatures of the relevant starch and often below the gelatinization

temperatures which depend on the specific moisture contents used for the treatment. Heat-moisture treatment effect on changing the functional properties of wheat, maize, potato, barley, cassava, yam, and legume starches were reported by many researchers [8–11]. It was observed that the HMT has increased the gelatinization temperature, enzymatic susceptibility, solubility, swelling volume, and changes in the X-ray diffraction patterns. The changes in these parameters vary depending on the source of the starch and the HMT conditions.

Temperature and moisture conditions are often selected without considering the exact gelatinization temperature of the starch at that particular moisture level, and the observed results on HMT may have been affected by the partial gelatinization of starch [12]. Not much work was done or reported on the effects of HMT at different combinations of temperature-moisture levels and treatment times on the properties of sweet potato starch. This study was done to observe the effect of different heat-moisture conditions on the swelling power and the water soluble index of five different cultivars of sweet potato (*Ipomea batatas* (L). Lam) starch.

2. Materials and Methods

Matured tubers of sweet potatoes, namely, swp 1 (Wariyapola red), swp 5 (Malaysian variety), swp 7 (CARI 273), swp 3 (Wariyapola white), and swp 4 (Pallepola variety) were collected from different areas in Dambulla, Gokarella, and Horana regions, Sri Lanka. Random samples selected from market areas have been identified at the Horticultural Crop Research and Development Institute, Gannoruwa, Kandy, Sri Lanka. Starch samples were prepared two to three days after harvesting.

2.1. Starch Extraction. Starch separation was carried out according to the method described by Takeda et al. [13] with slight modifications. Fresh tubers were washed, peeled, diced, and dipped in ice water containing 100 ppm sodium metabisulphite to minimize browning. Diced sample was wet milled at low speed in a laboratory scale blender with 1 : 2 w/v of tap water for 2 minutes and filtered through a gauze cloth. Residue was repeatedly wet milled and filtered for thrice, and suspension was kept overnight for settling of starch. The supernatant was decanted, and the settled residue was further purified with repeated suspension in tap water (1 : 2 v/v) followed by the settling for 3 hours. The purified starch was dried at 35°C, sifted through 300 μm sieve, sealed, and packed for analysis.

2.2. Heat-Moisture Treatment (HMT). Starch samples (20 g) were adjusted to 20%, 25%, and 30% moisture levels and placed in tubes with a sealing cap and equilibrated at room temperature for 12 hours. Samples were heated at 85°C and 120°C for 6 hours. Occasional shaking was done to samples within the treatment period for homogeneous distribution of moisture. After treatment, the samples were cooled to room temperature and dried at 40°C to a uniform moisture level of 10% and equilibrated at room temperature for 2 days.

2.3. Swelling Power (SP) and Water Soluble Index (WSI). Swelling power (SP) of the native and the HMT treated starch was determined according to the method of Gunaratne et al. [14]. Starch (100 mg, db) was weighed directly into a screw-cap test tube, and 10 mL distilled water was added. The capped tubes were placed on a vortex mixer for 10 seconds and incubated at 85°C water bath for 30 minutes with frequent mixing. The tubes were cooled to room temperature in an iced water bath and centrifuged at 2000 ×g for 30 minutes; the supernatant was removed, and the remaining sediment in the tube was weighed (W_s). The supernatant was dried to constant weight (W_1) in a drying oven at 100°C. The water swelling power was calculated as follows:

$$\mathrm{SP} = \frac{W_s}{[0.1 \times (100\% - \mathrm{WSI})]}\,(\mathrm{g/g}), \tag{1}$$

where WSI = $W_1/0.1 \times 100\%$.

2.4. Statistical Analysis. Results were subjected to general linear model, and analysis of variance (ANOVA) and correlation analysis for this study were carried out by using MINITAB version 14.

3. Results and Discussion

Results showed a significantly high level ($P < 0.05$) of swelling power and water soluble index in all the cultivars of HMT starch than their native starch (Tables 1 and 2). Also the results indicated a significant effect of cultivar, temperature, and moisture-temperature combination on the variation of SP in HMT starch and also showed no effect from the used moisture contents ($P < 0.05$). Correlation analysis showed a significant level of influence on SP by the moisture-temperature combination (Figure 1).

Lowest level of SP was found in the native starch of Swp 7 and comparatively high level of increase in SP was observed after the heat-moisture treatment, than the other cultivars. High level of swelling in all the cultivars of HMT starch than the native starch may be due to the amylose which complex with lipids in starch granules that are in helical form may change its physical form due to HMT and becomes more amorphous so that it can readily combine with moisture and increase swelling. But in most recent studies by researchers [8, 15] revealed a decrease in swelling with varying levels of HMT.

There is no significant difference ($P > 0.05$) in SP in the moisture-temperature combinations, 20%, 85°C, 20%—85°C, 20%—120°C, and 25%—120°C. Combinations of 25%—85°C, and 30%—85°C—had the lowest SP at the level $P > 0.05$, and significantly highest level of SP was observed in the 30%—120°C—combination. From the total correlation analysis of moisture-temperature combination, significantly high levels of SP ($P > 0.05$) were observed in 20%—85°C, and 30%—120°C. Therefore, 20%—85°C—can be used economically in increasing the swelling power of native starch.

Correlation analysis revealed there is no significant effect ($P < 0.05$) on WSI from the cultivar type, moisture level, and the moisture-temperature combination (Figure 2) but temperature affects the WSI significantly. Therefore, all moisture levels with 120°C temperature showed higher WSI than

Table 1: Changes in swelling power (g/g) of different sweet potato starches after 6 hr HMT.

		Swp 1	Swp 3	Swp 4	Swp 5	Swp 7
Native starch		7.9 ± 0.1^{e}	8.7 ± 0.2^{d}	8.7 ± 0.1^{d}	8.0 ± 0.1^{e}	5.8 ± 0.1^{d}
Temperature	Moisture					
85°C	20%	11.5 ± 1.2^{d}	12.0 ± 0.9^{a}	12.5 ± 0.8^{a}	12.1 ± 0.2^{c}	8.5 ± 0.7^{c}
	25%	12.9 ± 0.5^{d}	$10.5 \pm 0.5^{b,c}$	11.4 ± 0.2^{b}	11.0 ± 0.6^{c}	5.8 ± 0.3^{d}
	30%	$13.9 \pm 0.2^{a,c}$	10.1 ± 0.3^{b}	10.3 ± 0.4^{c}	9.7 ± 0.7^{d}	5.4 ± 0.2^{d}
120°C	20%	15.4 ± 0.3^{a}	10.5 ± 0.3^{b}	12.6 ± 0.2^{a}	11.8 ± 0.1^{c}	10.0 ± 0.2^{b}
	25%	$15.7 \pm 0.2^{a,b}$	$11.6 \pm 0.1^{a,b}$	$11.7 \pm 0.2^{a,b}$	13.1 ± 0.1^{b}	10.3 ± 0.1^{b}
	30%	$14.3 \pm 0.2^{a,b,c}$	$10.1 \pm 0.1^{b,c}$	12.8 ± 0.1^{a}	15.1 ± 0.1^{a}	12.1 ± 0.1^{a}

Values represented by different superscripts in each column are different at $P > 0.05$ level.

Table 2: Variation of water soluble index (%) in different sweet potato starches after 6 hr HMT.

		Swp 1	Swp 3	Swp 4	Swp 5	Swp 7
Native starch		1.6 ± 0.1^{d}	1.8 ± 0.1^{f}	1.3 ± 0.1^{e}	2.1 ± 0.1^{e}	0.5 ± 0.1^{d}
Temperature	Moisture					
85°C	20%	3.9 ± 0.2^{c}	3.2 ± 0.3^{e}	4.2 ± 0.3^{d}	4.1 ± 0.3^{d}	2.8 ± 0.3^{c}
	25%	3.3 ± 0.4^{c}	4.1 ± 0.4^{d}	$5.0 \pm 0.1^{b,c}$	2.3 ± 0.6^{e}	3.5 ± 0.5^{c}
	30%	$8.6 \pm 0.6^{a,b}$	5.6 ± 0.2^{c}	6.1 ± 0.3^{f}	4.1 ± 0.3^{d}	2.4 ± 0.2^{c}
120°C	20%	9.2 ± 0.2^{a}	8.5 ± 0.5^{b}	4.7 ± 0.2^{c}	6.6 ± 0.2^{c}	7.8 ± 0.1^{b}
	25%	9.0 ± 0.2^{a}	9.6 ± 0.1^{a}	5.5 ± 0.2^{b}	11.5 ± 0.3^{a}	8.2 ± 0.1^{b}
	30%	8.1 ± 0.1^{b}	8.5 ± 0.1^{b}	7.7 ± 0.2^{a}	9.1 ± 0.2^{b}	13.5 ± 0.3^{a}

Values represented by different superscripts in each column are different at $P > 0.05$ level.

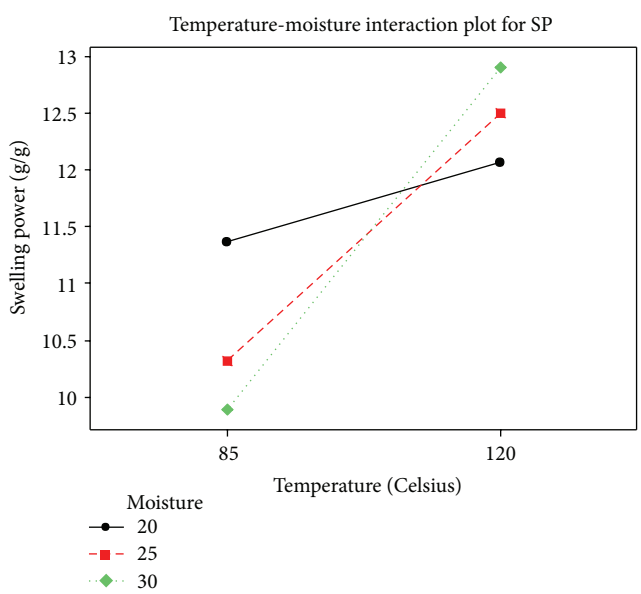

Figure 1: Temperature-moisture combined effect on swelling power (SP) of different starches.

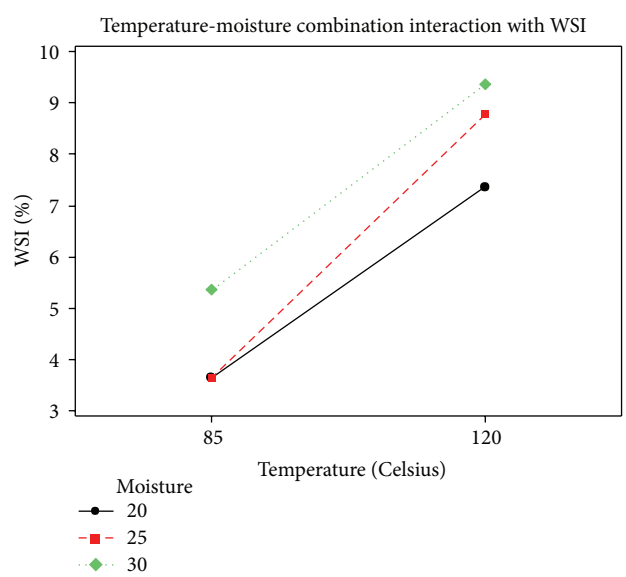

Figure 2: Temperature-moisture combined effect on WSI of different starches.

the combinations at 85°C. From all the combinations 30% moisture and 120°C had the highest level of WSI (Table 2).

Previous studies indicate different trends of change in solubility or WSI in various starches due to HMT [8, 15]. This may be also due to the fact that physical change in starch granules due to heat-moisture treatment. Our results indicate that the higher temperature used for HMT had more WSI than the lower temperature used. Higher solubility of starch may be due to the degradation of starch at higher temperatures. When considering the relationship between SP and WSI, there is a slight positive linear correlation (Pearson correlation coefficient 0.489). Analysis also indicated that there is no significant effect ($P < 0.05$) on the SP and WSI relationship from the cultivar type and moisture but slight effect from the temperature.

Overall results for HMT of native starch for 6 hrs have shown increased levels of SP and WSI than the native starch, and it is recommended to carry out the observations for different time periods with more variations in moisture-temperature combinations to get a more conclusive idea in this area.

4. Conclusion

The application of HMT on native starch showed increased levels of swelling and solubility thus obtained higher values for SP and WSI than their native counterparts. Results indicated a significant level of effect from moisture-temperature combination on SP and increase in WSI due to high level of temperature. Overall results showed the highest level of SP and WSI in moisture-temperature combination of 30%—120°C, and swp 7 cultivar had the highest level of increase in SP and WSI than its native form compare to other cultivars.

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