SHORT REPORTS

J.Sci.Soc.Thailand, 15 (1989) 39–47

MODIFICATION OF POTATO (*SOLANUM TUBEROSUM* VAR. *SPUNTA*) STARCH FOR PARTIAL SUBSTITUTION OF MUNG BEAN STARCH IN VERMICELLI

VORANUCH SRIJESDARK, VANNA TULYATHAN AND CHAIYUTE THUNPITHAYAKUL

Department of Food Technology, Faculty of Science, Chulalongkorn University, Bangkok 10500, Thailand.

(Received 17 October 1988)

ABSTRACT

In the modification of the potato starch by a crossbonding reaction, it was found that increasing temperature (40° to 50° C), time (4 h to 6 h) or concentration of sodium trimetaphosphate (0.20% to 0.30%) significantly decreased the Brabender viscosity at 95° C and the degree of set back of the potato starch ($p < 0.05$). For the combined effect of parameters on the crosslinking reaction, it was found that the effect of time × concentration of sodium trimetaphosphate, temperature × time, and temperature × concentration of sodium trimetaphosphate were all synergistic.

One crossbonded starch, modified with 0.30% sodium trimetaphosphate at 50 ± 2° C for 4 h, had swelling power similar to mung bean starch and could be used to substitute 52% of mung bean starch in vermicelli product. The vermicelli product obtained had qualities similar to grade A vermicelli (East Vermicelli Company) that was made from mung bean starch and imported potato starch in the ratio of 90:10.

INTRODUCTION

Potato (*Solanum tuberosum* var. Spunta and Kennebec) is one of the plants which is encouraged by the Office of the Narcotic Control Board for hilltribe people to grow in place of narcotic plants. During the peak season, the amount of potato produced is in excess of demand due to the limited use in the food industry. Settaudom[1] examined the utilization of the potato starches, both Kennebec and Spunta varieties, for bean vermicelli processing. She found that about 50% of mung bean starch could be substituted with potato starch.

However, rehydration and swelling after cooking of vermicelli products prepared with potato starch in this way were greater than in normal vermicelli made with mung bean starch. Since rehydration after cooking of vermicelli is an important quality, some modifications of the potato starch were suggested.

The objectives of this research were to chemically modify the potato starch so that the resulting product would have some properties similar to mung bean starch and would be able to partially substitute for some of the mung bean starch in vermicelli. Both grade A and B vermicelli products of East Vermicelli Company were used for comparison. Crossbonding with sodium trimetaphosphate was chosen as the modification reaction and the method of Kerr *et al.*[2] was modified for the experiment.

MATERIALS AND METHODS

1. Preparation of Starch

Potato tubers (*Solanum tuberosum* var. Spunta) were supplied by the Office of the Narcotic Control Board, Thailand. Potato starch was prepared according to the procedure of Settaudom.[1] The process is shown in Fig. 1 (mung bean starch was supplied by East Vermicelli Company).

Potatoes
↓
Water → Washing
↓
Chopping
↓
$NaHSO_3$ 0.075% w/v → Grinding with a Colloid Mill
↓
Screening (Sieve 75 mesh)
↓ → Coarse fiber
Screening (Sieve 200 mesh)
↓ → Finer materials
Sedimentation
↓ ← Wash twice
Starch
↓
Drying at 50 ± 2° C 6 h (moisture content 12.86%)
↓
Pack in polyethylene bags

Fig. 1 Preparation of potato starch.

2. Modification of the starch

Sodium trimetaphosphate ($Na_3P_3O_9$) (commercial grade, 67% purity) was used as a crossbonding reagent. The starch was crossbonded according to the procedure modified from Kerr *et al.*[2] as shown in Fig. 2. The study was designed as a factorial using two temperature, two reaction times and two concentrations of sodium trimetaphosphate with two replications. The following conditions were varied for crossbonding :

temperature	40 ± 2° C and 50 ± 2° C
time	4 and 6 h
$Na_3P_3O_9$	0.20 and 0.30% of dry starch

Solution of Na_2CO_3 (0.03 M) and $Na_3P_3O_9$
(140 ml)
↓ ← starch 100 gm, 0.4 M NaOH

[Starch slurry pH 11 ± 0.1 → Stirring] Control temperature and time

↓
Cool to room temperature
↓
Adjust pH to 6.65 with 1.5 M HCl
↓
Filter
filtrate ← ↓ ← Wash twice
Modified starch
↓
Drying at 50 ± 2° C 15 h
↓
Crossbonded starch
↓
Pack in polyethylene bags

Fig. 2 Preparation of crossbonded starch.

3. Chemical analysis

Moisture content of the starches was determined as described in AOAC.[3] Phosphorus content was determined by the method of Smith and Caruso.[4]

4. Physical properties of the starches

Brabender viscoamylograms of the starches were determined at 4% concentration (dry weight basis) using a Brabender ViscoAmylograph (Brabender-OHG Duisburg, Germany) with a 700-cmg cartridge and a temperature range of 30-95-30°C. Graphical analysis of the Brabender curves were analyzed according to the procedure described by Mazur *et al.*[5]

Swelling power was determined at 10°C intervals from 65° to 95°C by the procedure described by Leach *et al.*[6]

RESULTS AND DISCUSSION

Brabender viscoamylograms of the native potato starch and mung bean starch are shown in Fig. 3. The amylogram of the potato starch show no pasting peak similar to that of mung bean starch.

Swelling power of the starches are shown in Fig. 4. The results indicate that mung bean starch have more restrictedswelling power than potato starch. The swelling power and the high pasting temperature (75°C) of mung bean starch (Fig. 3) suggest that the starch granules have strong internal bonding forces.

Chemical analysis of the crossbonded starches

Phosphorus content of the crossbonded starches are shown in Table 1. The results indicate that as temperature (40 ± 2°C, 50 ± 2°C), time (4 h, 6 h) or concentration of $Na_3P_3O_9$ (0.20%, 0.30%) are increased, phosphorus contents of the crossbonded starches also increased.

Physical properties of the crossbonded starches

Brabender viscoamylograms of the crossbonded starch are shown in Fig. 3. The results show that the viscosity of the crossbonded starches increased perceptibly during cooking. With starch treated at 50 ± 2°C, all the crossbonded starches had lower viscosity than the native potato starch. This was due to the covalent phosphate ester bonds which restricted and retarded the swelling of the granules during cooking. At 40 ± 2°C, the viscosity at 95°C 30 min of the crossbonded starches, modified with $Na_3P_3O_9$ 0.20% 4 and 6 h and $Na_3P_3O_9$ 0.30% 4 h, were higher than the native starch. The results are similar to that of Kite.[7]Kite found that at low level of crossbonding, modified corn starches had higher viscosity than the native starch.

Temperature, time and concentration of $Na_3P_3O_9$ had effect on the viscosity at 95°C of the crossbonded starches. It was found that increasing temperature (40° to 50°C) or time (4 h to 6 h) or concentration of $Na_3P_3O_9$ (0.20% to 0.30%) decreased the viscosity at 95°C of the starch pastes significantly ($p < 0.05$). For the combined effects of parameters, it was found that increasing temperature and concentration, temperature and time, concentration and time would significantly ($p < 0.05$) decrease the viscosity at 95°C.

Table 2 shows the degree of set-back of the crossbonded starches. In this experiment, the degree of set-back on cooling was the difference between viscosity at 95°C 30 min and the maximum viscosity at 50°C. The results show that increasing temperature or time or concentration of $Na_3P_3O_9$ would decrease the degree of set-back significantly ($p < 0.05$). Mazur *et al.*[5] explained that as crossbonding proceeded, set back on cooling of crossbonded starch pastes would take place within the swollen granules, not in the aqueous substrate, and consequently the set-back on cooling is minimal. At very high crossbonding, no gelatinization occurs.

Crossbonding reaction also increased the pasting temperature of the crossbonded starches. The results are shown in the viscoamylograms (Fig. 3) which are shifted to the right of the native starch.

Viscoamylograms, degree of set-back and pasting temperature of the crossbonded starches indicate the presence of stronger bonding forces within the granules than in the native potato starch. The crossbonded starches which had highest Brabender pasting temperature and lowest viscosity were the starches modified under the following conditions (a) 40 ± 2°C 0.30% $Na_3P_3O_9$ 6 h and (b) 50 ± 2°C 0.30% $Na_3P_3O_9$ 6 h (Fig. 3).

Partial substitution of mung bean starch with the crossbonded starch in vermicelli product

One crossbonded starch was selected for the study. The starch was modified at 50 ± 2°C, 0.30% $Na_3P_3O_9$, 4 h (Fig. 3). Swelling power of the starch and mung bean starch are reported in Fig. 4. The results show that swelling power of the crossbonded starch is similar to that of mung bean starch.

The bean vermicelli in this experiment was made at East Vermicelli Company. The process is shown in Fig. 5.

Starch Paste
(Starch : water = 1 : 9)
↓ ← Starch (raw)
Mixing and Kneading
↓
Bean threading machine
↓ (Raw vermicelli)
Hot water bath, 95°C
↓
Cold water bath, 25-30°C
↓
Cooked vermicelli
↓
Hang on bamboo and sun dry
↓
Cold storage, −4°C
↓
Sun dry
↓
Bean vermicelli (moisture content 14%)

Fig. 5 Processing of bean vermicelli.

The vermicelli products made from the crossbonded starch and native potato starch were compared with grade A and B vermicelli products of East Vermicelli Company.

Ratio of rehydration and loss of soluble starch of the vermicelli products were determined by the methods of Settaudom.[1] Average size of vermicelli threads was determined according to the procedure described in Standard for Bean Vermicelli.[8]

It was found that there were no significant differences ($p < 0.05$) between the vermicelli product substituted with 52% of the crossbonded starch and the grade A vermicelli product of the East Vermicelli Company (Thailand). By substitution with 52% crossbonded starch, the amount of soluble starch lost during cooking of vermicelli was significantly lower ($p < 0.05$) than in the vermicelli substituted with 30% native potato starch (Spunta).

REFERENCES

1. Settaudom, C. (1986). Effects of Process Variables on Quality of Potato Starch Produced from Potatoes Grown in Thailand. M.S. Thesis. Chulalongkorn University, Bangkok.
2. Kerr, R.W., Cleveland, F.C. and Chiegg,Jr. (1957). Process for the Preparation of Distarch Phosphate and the Resultry Products. U.S. Pat 2, 081, 242, July 30.
3. AOAC. (1980). Official Method of Analysis. 13th ed. Association of Official Agriculture Chemists, Washignton, D.C.
4. Smith, R.J. and Caruso, J.L. (1964). Determination of Phosphorus. *Determination of Phosphorus.* In : Starch, Method in Carbohydrate Chemistry (Whistler, R.L., Smith, R.J. and Bemiller, J.N., eds.), Academic Press, New York, pp. 42-46
5. Mazurs, E.G., Schoch, T.J. and Kite, F.E. (1957). Graphical Analysis of the Brabender Viscosity Curves of Various Starches. *Cereal Chem.* **34,** 141-152.
6. Leach, H.W., McCowen, L.D. and Schoch, T.J. (1959). Structure of the Starch Granules. I. Swelling and Solubility Patterns of Various Starches. *Cereal Chem.* **36,** 534.
7. Kite, F.E. (1971). *The Use of Phosphates in Food Products.* In : Symposium , Phosphate in Food Processing (Deman, J.M. and Melnychyn, P., eds.), AVI Publishing Co. Inc.,Westport, Connecticut, pp. 103-119.
8. Standard for Bean Vermicelli. (1983). UDC. 664.26.694. Ministry of Industry, Bangkok, Thailand.

บทคัดย่อ

ศึกษาการแปรสภาพแป้งมันฝรั่งด้วยปฏิกิริยาพันธะเชื่อมข้าม พบว่าการเพิ่มอุณหภูมิ (40 ถึง 50 องศาเซลเซียส) เวลา (4 ถึง 6 ชม.) หรือความเข้มข้นของโซเดียมไตรเมตาฟอสเฟต (0.20% ถึง 0.30%) ค่าความหนืดบราเบนเดอร์ที่ 95 องศาเซลเซียส และค่าการคืนตัวของแป้งสุกจะลดลงอย่างมีนัยสำคัญทางสถิติ ($p < 0.05$) ผลของปฏิกิริยาร่วมระหว่างตัวแปรพบว่าผลของ เวลา × ความเข้มข้นโซเดียมไตรเมตาฟอสเฟต อุณหภูมิ × เวลา และ อุณหภูมิ × ความเข้มข้นโซเดียมไตรเมตาฟอสเฟต จะเสริมกัน

แป้งแปรสภาพด้วยโซเดียมไตรเมตาฟอสเฟต 0.30% ที่อุณหภูมิ 50 ± 2 องศา เซลเซียส เวลา 4 ชม. มีกำลังพองตัวใกล้เคียงกับแป้งถั่วเขียวและสามารถทดแทนแป้งถั่วเขียวในผลิตภัณฑ์วุ้นเส้นได้ 52% วุ้นเส้นที่ได้มีคุณภาพใกล้เคียงกับวุ้นเส้นเกรดเอ (บริษัทวุ้นเส้นตะวันออกจำกัด) ที่ผลิตจากแป้งถั่วเขียวผสมแป้งมันฝรั่งในอัตราส่วน 90 : 10

TABLE 1 Phosphorus Content of Modified Potato Starches

Starch	% Phosphorus × 10^2	% Increased of phosphorus × 10^3
Potato	6.9048	
0.20% 40 ±2°C 4 h	7.0286	1.238
0.20% 40 ±2°C 6 h	7.2010	2.962
0.20% 50 ±2°C 4 h	7.2275	3.227
0.20% 50 ±2°C 6 h	7.4145	5.097
0.30% 40 ±2°C 4 h	7.1700	2.652
0.30% 40 ±2°C 6 h	7.3550	4.502
0.30% 50 ±2°C 4 h	7.6883	7.835
0.30% 50 ±2°C 6 h	7.7548	8.500

TABLE 2 Degree of Set Back of Modified Potato Starches

Conditions			Average degree of set back (B.U.)
Concentration	Temperature	Time	
a_1 = 0.20%	b_1 = 40 ±2°C	c_1 = 4 h	1281.5
		c_2 = 6 h	921.5
	b_2 = 50 ±2°C	c_1 = 4 h	677.5
		c_2 = 6 h	251.0
a_2 = 0.30%	b_1 = 40 ±2°C	c_1 = 4 h	376.5
		c_2 = 6 h	190.0
	b_2 = 50 ±2°C	c_1 = 4 h	135.5
		c_2 = 6 h	16.0

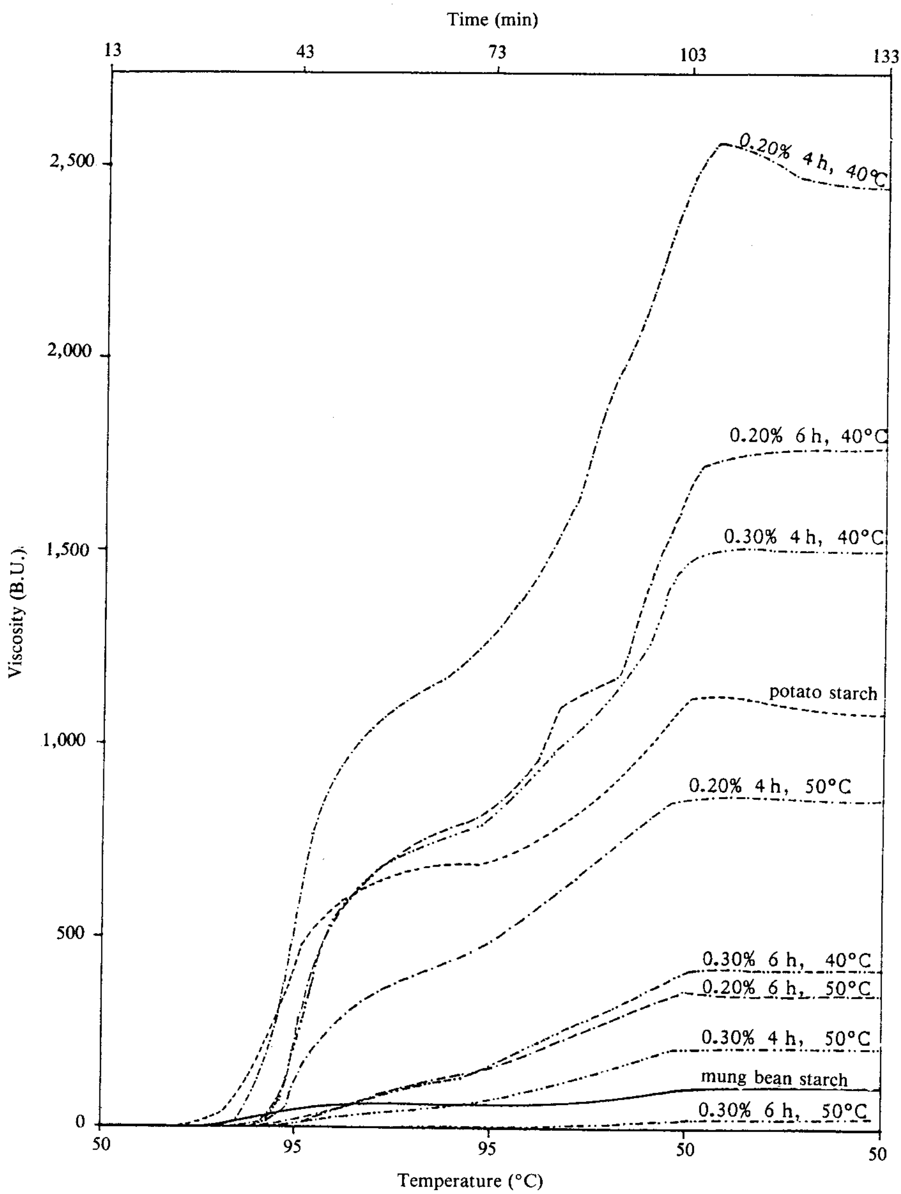

Fig.3 Brabender viscosity of potato starch after modification using different concentrations of sodium trimetaphosphate at 40 ± 2°C and 50 ± 2°C.

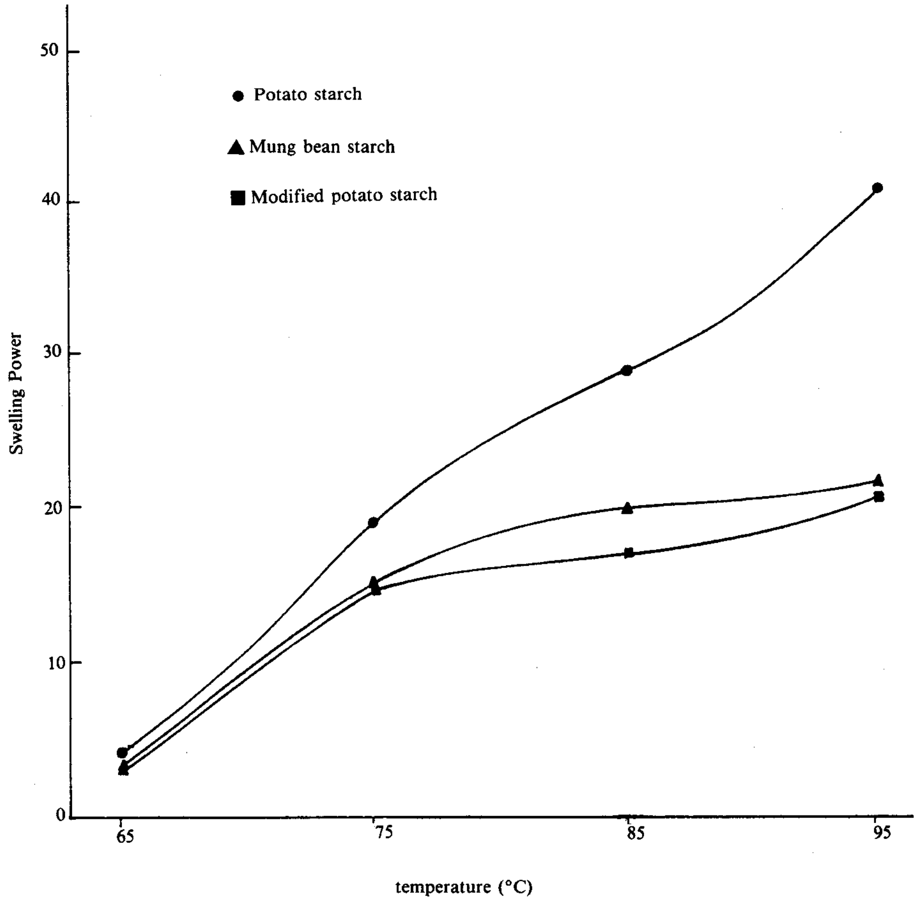

Fig.4 Swelling power of starch granules at different temperatures.