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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Characterization of banana, potato, and rice starch blends for their physicochemical and pasting properties

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Abstract: The properties of blends of banana, potato, and rice starches were studied to assess their suitability as an alternate for chemically modified starches. The blends of banana, potato, and rice starches were prepared in the respective ratio of 1:3:2, 3:2:1, and 2:1:3. The blend with higher proportion of banana and rice starches (BPR-213) showed highest water absorption capacity and oil absorption capacity. The blend with higher proportion of banana starch (BPR-321) showed highest swelling power at 95°C but lowest water solubility at 95°C among other starch blends. The blend made with higher amount of potato starch (BPR-132) had significantly higher paste clarity than other blends ($p < 0.05$). The potato starch had significantly higher least gelation concentration than all other starches and their blends ($p < 0.05$). The banana starch and blend with highest proportion of banana starch (BPR-321) showed significantly lesser percent syneresis and thus highest freeze–thaw stability. Potato starch as well as it blends with greater amount of potato starch (BPR-132) showed highest value for peak viscosity, hot paste viscosity, and final viscosity than other blends.

Subjects: Bioscience; Environment & Agriculture; Food Science & Technology

Keywords: starch blends; physicochemical properties; freeze–thaw stability; pasting properties

ABOUT THE AUTHORS

The authors are involved in the research activities mainly based upon modification, characterization, and application of the native and modified starches for the development of the products like noodles. The starches from diverse sources like rice, amaranth, buckwheat, pearl millet, cowpea, colocasia, banana, potato, water chestnut, etc. have been modified using physical and chemical modification methods and characterized for their physicochemical and functional properties. *In vitro* digestibility and resistant starch determination is another aspect on which the authors are working. Extending the domains of modification of starches further, the objective of the current research study was to explore and assess the suitable blends of starch having altered properties so that these can be used as alternates to the chemically modified starches. This approach will not only keep starches as natural as these are, but also reduce the problem of environmental pollution caused by the chemical waste of the starch industry.

PUBLIC INTEREST STATEMENT

Market demand for natural foods is growing rapidly, which has necessitated the search for consumer friendly and environment friendly alternatives for food ingredients and additives. Starches with novel properties and functionalities have attracted the interest of researchers and food processors for wide applications in foods. Starches from different botanical sources can be blended to achieve the modified functionality without any chemical or physical modification. Blends of banana, potato, and rice starches were found to have desirable modified properties over their native individual counterparts. Starch blends with higher proportion of banana starch can be suitable for products which are frozen and thawed. Higher proportion of potato starch in the blends provides clarity to the starch pastes. Such starch blends retain their naturalness and safety as no chemicals are used for modification. Native starch blends are increasingly applied in food industry to replace chemically modified starches.

1. Introduction

Starch is an important storage product in plants acting as a main energy source in human diet. Starch is very comprehensive as it can be obtained from various botanical sources and it may differ in granular morphology, molecular weight, composition, and physiochemical properties. Commercial starches are commonly obtained from various plant sources such as wheat, maize, rice, potato, and banana. Depending on the source, starches have different properties resulting in varied applications in improving consistency, stability, and other properties of foods (Smith, 1982). Starches are attractive food ingredients for texture modification because they are natural and safe (Mishra & Rai, 2006). Not only is the amount of starch important for the texture of a given product, but starch type is equally critical (Biliaderis, 1991). Starches with novel properties and functionalities have attracted the interest of researchers and industry for wide applications in food and other industries. Each starch has unique functional properties, but most of those used by industries are modified before use, giving a wide range of useful products. Chemical modification is widely used to attain desirable functional properties for a wide range of utilization; however, with the growing market demand for natural food, there is greater necessity to search for alternatives to chemical modification. One possibility may be the use of blends of different starches, although this is not a common practice not much work has been done in this area despite its high potential. Native starch blends are increasingly applied in food industry to make starchy foods with a desired rheological property, texture, or storage stability, or to replace modified starches (Obanni & Bemiller, 1997). Jane and Chen (1992) blended amyloses and amylopectins from diverse botanical sources and reported synergistic effects on paste viscosity. Obanni and Bemiller (1997) found that pasting properties of some starch blends behaved similarly to cross-linked starches and the tendency to retrograde decreased after blending. Karam, Grossmann, Silva, Ferrero, and Zaritzky (2005) found that blending native starches from maize, cassava, and yam improves some specific sensory properties. In contrast to single starch systems, starch blends generally exhibit unique viscoelastic or physical properties that cannot be directly interpreted by the final apparent amylose content or mixing ratio (Lin, Aboubacar, Zehr, & Hamaker, 2002; Obanni & Bemiller, 1997). This may be because of the differences in swelling power and solubility between different starches (Chen, Lai, & Lii, 2003; Ortega-Ojeda & Eliasson, 2001) and the uncertainties involved in intermolecular association (Lin et al., 2002; Obanni & Bemiller, 1997). Stute and Kern (1994) patented blends of starches for use in pudding preparation. The patent claimed that the use of blends of unmodified pea and corn starches in ratio of 9:1 to 1:9 as gelling and texturing agent in formulation of food products reduces syneresis. The swelling factor, extent of amylose leaching, pasting, and gel textural properties of the blends of sweet potato and wheat starches were non-additive of their individual components but the gelatinization and retrogradation enthalpies (δH) of the blends were additive of their individual components (Zhu & Corke, 2011). Similarly, non additive behavior in relation to pasting properties was observed in mixtures of potato and maize starch (Zhang, Gu, Hong, Li, & Cheng, 2011). It is possible to formulate starch blends from unmodified starches that possess at least some of the desired characteristics of modified starches. However, further characterization of blends is necessary to determine the optimum ratio of starches that provides the desired functional properties. The objective of this study was to examine the functional properties of rice, banana, and potato starches and their blends.

2. Materials and methods

2.1. Isolation of banana starch

Bananas (*Musa paradisiaca*) were purchased from the local market in Sirsa, India. The starch was isolated using method of Kim, Wiesenborn, Orr, and Grant (1995) with some modifications. The fruits were peeled and cut into 5–6 cm cubes. The cubes were rinsed immediately and homogenized with sodium sulfite solution (1.22 g/l) at low speed in a laboratory blender (Remi, India) (500 g fruit: 500 g solution) for 2 min. The homogenate was consecutively sieved through screens of 0.300, 0.250, 0.150, 0.106, 0.075, 0.050, and 0.045 mm sieves until the washing water was clean. The filtrate was centrifuged at 10,800×g for 30 min (C-24 BL; Remi, India). The white starch sediment was dried in a convection oven (NSW-143; NSW India) at 40°C for 48 h, ground with a mortar and pestle, and passed through 0.150 mm sieve. The starch was stored at room temperature in a sealed container.

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2.2. Isolation of potato starch

The potato starch was extracted by the method of Peshin (2001). The potatoes were washed, peeled, sliced, and crushed for 3–4 min in a mixer at room temperature using one liter distilled water for 1 kg of material. The material was passed through fine muslin cloth to separate cell debris and translucent suspension. The residue was resuspended in water and allowed to stand for 24 h at 6°C to increase the starch recovery. It was again crushed, sieved, and the supernatant containing starch was decanted. The starch was allowed to settle and the supernatant was decanted. The starch sediment was washed 3–4 times with distilled water, sieved through muslin cloth until the washing water was clear and free from suspended impurities. The pure extracted starch was dried in hot air oven at 40°C over night. The dried starch was ground to fine powder and stored in polythene bags.

2.3. Isolation of rice starch

Rice starch was isolated using alkali steeping method. Milled rice grains were steeped in five volumes of sodium hydroxide (0.2%) solution (Fisher Scientific) at 25°C for 24 h to soften the endosperms. The steep liquor was drained off and the rice grains were ground with pestle and mortar. The slurry was diluted to the original volume with (0.2%) sodium hydroxide. The mixture was stirred for 10 min and allowed to settle overnight. The cloudy supernatant was drained off and the sediment was diluted to the original volume with sodium hydroxide solution. The process was repeated for 5–6 times. Starch was suspended in twofold distilled water and centrifuged at 1,400×g for 10 min. Again the starch was washed with twofold volumes of distilled water four times, dried in a hot air oven at 40°C for 48 h, passed through a 0.150 mm sieve, and stored in plastic jar at room temperature.

2.4. Starch blends

Blends of banana, potato, and rice starch were prepared respectively in the ratio of 2:1:3; 1:3:2, and 3:2:1 to study their functional properties and pasting properties.

2.5. Chemical analysis

Crude protein, crude fat, moisture, and ash contents of native banana, potato, and rice starch were determined using standard methods of Association of Official Analytical Chemists (1984). Total starch content was determined using anthrone's reagent method. Amylose content was determined using method as described by Williams, Kuzina, and Hlynka (1970).

2.6. Water absorption and oil absorption capacity

The water and oil absorption capacities were determined following the method of Sosulski, Garratt, and Slinkard (1976). The sample (1.0 g) was mixed with 10 ml distilled water or refined soybean oil and allowed to stand at room temperature (35°C) for 30 min. The contents were centrifuged at 2,000×g for 10 min. Water or oil absorption capacity (OAC) was expressed as percent water or oil bound per gram of starch.

2.7. Swelling power and solubility

The solubility and swelling power were determined using method as suggested by Lauzon et al. (1995) with some modification. The starch dispersion (0.5 g starch in 25 ml distilled water) was heated at different temperatures of 55, 65, 75, 85 and 95°C for 1 h with continuous shaking followed by rapid cooling to room temperature and centrifugation at 1,900×g for 15 min. The percentage of solubility and swelling power were calculated as given below:

$$\% \text{ Solubility} = \frac{\text{Weight of dried sample} \times 100}{\text{Sample weight}}$$

$$\% \text{ Swelling power} = \frac{\text{weight of wet sample} \times 100}{\text{Sample weight} \times (100 - \% \text{ solubility})}$$

2.8. Paste clarity

The stability and clarity of the starch paste was determined at 4 and 30°C after a storage period of 24, 48, 72, and 96 h (Bello-Pérez, Roger, Baud, & Colonna, 1998). Starch paste was prepared by suspending 0.2 g of starch in 5 ml water in a screw cap test tube and keeping it in a boiling water bath for 30 min. The test tubes were thoroughly shaken after every 5 min. The contents were cooled to room temperature and % transmittance was measured at 650 nm using a double beam spectrophotometer (117; Systronics India).

2.9. Least gelation concentration

The least gelation concentration (LGC) was determined by modified method of Coffmann and Garcia (1977). The starch dispersions of 20, 22, 24, 26, 28, 30, 32, 34 ... 40% (w/v) were prepared in 5 ml distilled water taken in test tubes and heated in a boiling water bath. The dispersions were cooled rapidly under running tap water and stored at 10 ± 2°C for 2 h. The LGC was determined as that concentration when the sample from the inverted tube did not slip.

2.10. Freeze–thaw stability

Freeze–thaw stability was determined following the procedure as used by Takizawa, Silva, Konkel, and Demiate (2004). Starch–water suspension (8%, w/w) was gelatinized in a boiling water bath for 10 min. The gel was poured on a standardized plastic cup and stored in freezer (−18°C for 24 h). The gel was thawed (2 h at 40°C), detached from the cup, and the weight of water loss was measured. The amount of free water was expressed as percentage of weight loss and two cycles of freeze–thawing were considered. All the samples, from the first and second cycles were frozen (−18°C for 24 h) and thawed (40°C for 2 h) together at the same conditions. For the second cycle, the cups containing the starch pastes were only thawed but the paste was kept inside the cup. After complete thawing, the cups were taken back to the freezer for more 24 h and then thawed again at 40°C for 2 h and the amount of free water weighed.

2.11. Pasting properties

Pasting properties of native starches and their blends were determined using a rapid visco analyzer (RVA Starch Master TM, Newport Scientific, Warriewood, Australia). Test profile STDI (Newport Scientific Method1, Version 5, 1997) was used for the determination of pasting characteristics. The sample (3.0 g) was dispersed in water (25.0 ml) and stirred in an RVA container initially at 960 rpm for 10 s and final at 160 rpm for the remaining test. The temperature profile was started from 50°C for 1 min followed by ramping the temperature linearly to 95°C in 3 min and 42 s, holding for 2 min, and 30 s, cooling the system to 50°C in 3 min and 48 s and ending the process in 13 min. The pasting curves obtained were analyzed using a RVA Starch Master Software setup Tool (SMST) to obtain the characteristic parameters like pasting temperature (PT), peak viscosity (PV), trough viscosity/holding strength, final viscosity, breakdown (peak viscosity − trough viscosity), and setback (final viscosity − trough viscosity). All measurements were performed in duplicate.

2.12. Statistical analysis

The data were analyzed statistically in a completely randomized design using one-factor and two-factors analysis of variance with the help of OPSTAT statistical analysis software.

3. Results and discussion

3.1. Chemical composition of native starches

The chemical composition of native starches of rice, potato, and banana is shown in Table 1. Rice starch had significantly ($p < 0.05$) higher ash content (0.84%) than those of banana and potato starches. The ash content of the banana and potato starches observed in the present study were reasonably in agreement with those observed by Bello-Perez, Meza-Leon, Contreras-Ramos, and Paredes-Lopez (2001). The protein content of different starches varied significantly and ranged from 0.13 to 0.39%. The protein content of banana, potato, and rice starches was in agreement with those reported in the previous studies (Bello-Perez et al., 2001; Deetae et al., 2008; Kayisu, Hood, &

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Table 1. Chemical composition of rice, potato, and banana starches

Content (%)	Rice starch	Potato starch	Banana starch
Moisture	6.10 ± 0.88[a]	15.35 ± 0.72[b]	7.56 ± 0.07[a]
Fat	0.02 ± 0.01[a]	0.02 ± 0.01[a]	0.04 ± 0.01[b]
Protein	0.39 ± 0.02[b]	0.13 ± 0.02[a]	0.28 ± 0.01[a]
Ash	0.84 ± 0.08[b]	0.32 ± 0.06[a]	0.22 ± 0.01[a]
Amylose	20.54 ± 1.77[c]	16.88 ± 2.06[a]	18.33 ± 1.23[b]
Total starch	93.06 ± 0.18[c]	90.40 ± 0.15[b]	86.97 ± 0.43[a]

Notes: The values are mean ± SD of three independent determinations.

The values in a given row with different superscripts are significantly different ($p < 0.05$).

Vansoest, 1981). Fat content of starches ranged from 0.02 to 0.04%. Banana starch had significantly higher fat content (0.04%) as compared with potato and rice starches ($p < 0.05$). The observed values of fat contents in starches were close to those reported by Bello-Pérez, Romero-Manilla, and Paredes-López (2000) and Raina, Singh, Bawa, and Saxena (2005). The amylose content of starches was in the range of 16.88–20.54% with rice starch exhibiting the highest amylose content. A significant difference was observed between the amylose content of rice and potato starches ($p < 0.05$). Amylose content of potato observed in the present study was reasonably similar to that reported by Peshin (2001). The observed amylose content of rice starch was close to those reported by Yadav, Yadav, and Kumar (2011). Amylose content of starches has very significant impact on the functional properties of starches. The total starch content in native starches were found to be in the range of 86.97–93.06% and varied significantly from each other ($p < 0.05$).

3.2. Water and oil absorption capacity

Water absorption capacity (WAC) of native starches and their blends ranged from 75.06 to 119.95% (Table 2). The potato starch had significantly lowest value (75.06%) of WAC in comparison to that of rice (119.95%) and banana starch (107.07%) ($p < 0.05$). The high WAC of rice starch might be due to its high protein content which made it more hygroscopic in nature. The OAC of native starches was significantly different from each other and ranged from 76.20 to 133.93% ($p < 0.05$). The mechanism of oil absorption is attributed to physical entrapment of oil by proteins (Kinsella, 1979). However, the hydrophobicity of proteins also plays a major role in oil absorption (Voutsinas & Nakai, 1983). Similarly, the blends with higher proportion of banana and rice starches i.e. BPR-213 showed highest WAC (108.63%) and OAC (99.93%) than the other blends.

Table 2. WAC, OAC, and LGC of native starches and their blends

Sample	Water absorption capacity (%)	Oil absorption capacity (%)	Least gelation concentration (%)
B	107.07 ± 5.52[bc]	102.79 ± 1.7[c]	27.33 ± 0.67[b]
P	75.06 ± 8.53[a]	76.20 ± 2.17[a]	42.00 ± 0.02[e]
R	119.95 ± 6.39[c]	133.93 ± 0.23[d]	28.67 ± 0.67[c]
BPR-132	100.07 ± 2.37[b]	86.76 ± 0.74[b]	30.00 ± 0.28[d]
BPR-321	102.97 ± 1.28[b]	83.10 ± 1.41[b]	30.00 ± 0.51[d]
BPR-213	108.63 ± 0.33[bc]	99.93 ± 2.33[c]	26.00 ± 0.02[a]

Notes: The values are mean ± SD of three independent determinations.

The values in a given column with different superscripts are significantly different ($p < 0.05$).

B denotes banana starch; P denotes potato starch; R denotes rice starch.

The numbers 132,321 and 213 show the ratios of three starches taken in blends in their respective order.

3.3. Least gelation concentration

LGC of starches and their blends were in the range of 26–42% (Table 2). The LGC of native starches varied significantly from each other ($p < 0.05$). The LGC concentration is the index of gelation properties. The potato had significantly higher LGC (42%) than all other starches and their blends ($p < 0.05$). Similarly, the blends with greater amount of potato starch showed higher LGC. It might be possible that LGC is directly affected by the amount of percent starch present in the starch sample and pasting properties of starches.

3.4. Swelling power

The swelling power of starches and their blends were assessed over temperatures of 55–95°C at intervals of 10°C (Figure 1). When starch granules are heated in excess of water, the crystalline structure gets disrupted and water molecules become linked by hydrogen bonding to the exposed hydroxyl group of amylose and amylopectin which brings about their dissolution and swelling. The swelling of starch was found to be a function of temperature prior to gelatinization. However, once the gelatinization process sets in, swelling increases rapidly with increasing temperature (Feroz, Khalid, & Abid, 2004). The swelling power was affected both by temperature and types of starches. An increase in swelling power was observed when temperature was increased from 65 to 95°C. This increase was even more rapid when the temperature was increased beyond 75°C. At higher temperature (95°C), the potato (33.41%), rice (17.58%), and banana (15.79%) starch had significant differences in their swelling powers ($p < 0.05$). However, no significant difference in the swelling power of native starches and their blends was observed at 65°C. But at 75°C, the swelling power of potato starch and the blend with higher potato starch concentration (BPR-132) was significantly higher than all the other native starches and blends. The potato starch showed a rapid swelling even at low temperature when compared with rice and banana starch because the potato starch has weak internal bonding and high swelling relatively at low temperature due to the presence of ionizable esterified phosphate groups which assist swelling by mutual electrical repulsion (Whistler & Paschall, 1965). The potato starch is known to have higher swelling due to presence of negatively charged phosphate groups which assist in increasing the swelling power of potato starch granules (Swinkels, 1985). The potato starch had overall significantly higher (14.93%) swelling power as compared with rice (9.02%) and banana (7.70%) starches ($p < 0.05$) irrespective of temperature. The difference in swelling behavior might be due to difference in the structure and chemical composition of starches. The different amylose/amylopectin ratio contributed to difference in swelling power (Sasaki & Matsuki, 1998). The rice starch had a lower swelling power in comparison to that of potato starch because cereal starches have highest degree of association which lowers the swelling power. The lowest swelling power (7.70%) of banana starch might be because of higher fat content which might have technological and nutritional importance due to the amylose–lipid complexes formed during the processing of this starch. Perhaps this is the principal reason that banana starch is resistant to amylolysis (Asp & Bjorck, 1992). Similarly, the swelling power of blends with high proportion of potato starch (BPR-132) showed significantly highest (11.60%) value among the starch blends ($p < 0.05$) irrespective of temperature. The starch blend (BPR-321) had greater swelling capacity (10.85%) in comparison to that of blend (BPR-213) (10.51%) because potato starch overcame the effect of banana and rice starches.

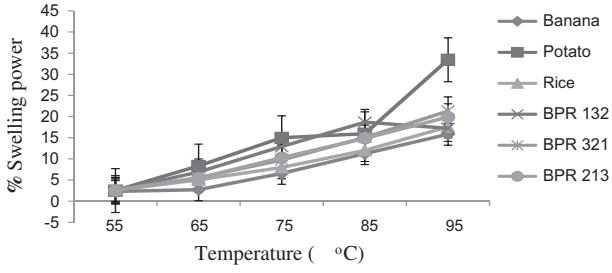

Figure 1. Effect of temperature on swelling power of native starches and their blends.

3.5. Water solubility

The water solubility of starches and their blends at different temperature is as shown in Figure 2. Solubility is a measure of the solutes which are leached out from starch granules when tested for swelling capacity. The solubility of starches was significantly affected by both temperature as well as type of starches. In native starches regular increase in solubility with increase in temperature was observed. But at higher temperature (85–95°C), there was sudden decrease in solubility. However, this trend was not observed in blends where the solubility increased at higher temperatures (85–95°C). There was tremendous increase observed in blend (BPR-132) at 65°C. Below the gelatinization temperature all starches were less soluble. The solubility of native starches did not show any significant difference at 65°C, but at 95°C it differ significantly ($p < 0.05$). Solubility of rice starch was significantly highest (12.53%) because of high amylose content which solubilized into the hot water ($p < 0.05$). The banana starch had lowest solubility (8.52%) because in presence of high fat content the amylose–lipid complex formed during processing decreased the solubility of banana starch. The solubility of blend with high rice and potato starch (BPR-132) was also found higher than other blends.

3.6. Paste clarity

The paste clarity of starches and their blends measured at refrigeration temperature and room temperature is shown in Figures 3 and 4, respectively. Difference in percent transmittance was observed among starches stored at 4°C and at room temperature (Figures 4 and 5). In general, paste clarity is directly related to the state of dispersion and the retrogradation tendency of starches. The starches having high swelling power and a low retrogradation tendency, which is amylose dependent, show good paste clarity, which is preferred for products requiring clear thickening agents as used in soups

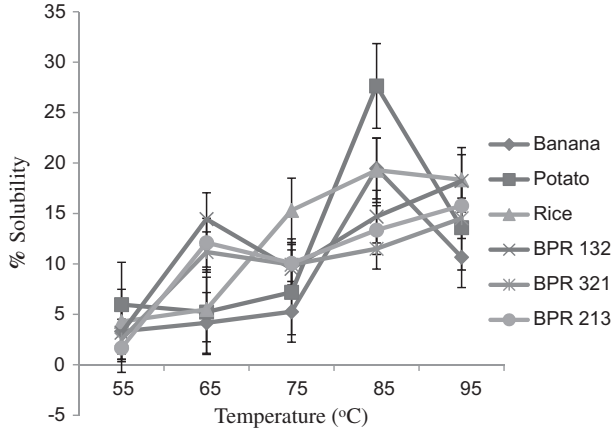

Figure 2. Effect of temperature on water solubility of native starches and their blends.

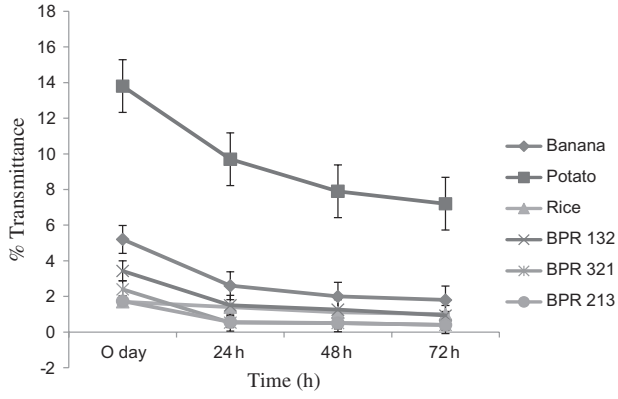

Figure 3. Effect of storage period on clarity of starch paste at refrigeration temperature.

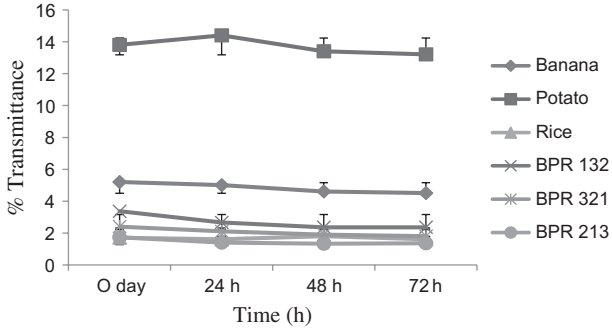

Figure 4. Effect of storage period on clarity of starch pastes at room temperature.

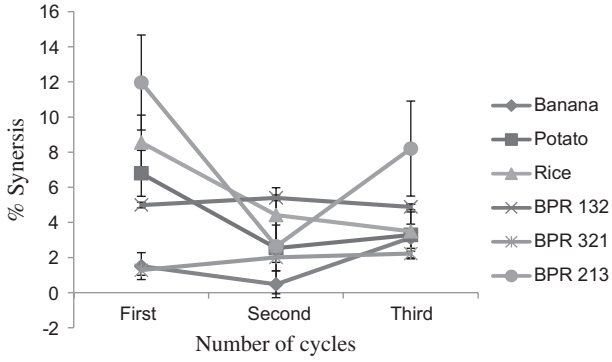

Figure 5. Effect of storage on % syneresis of native starches and their blends.

and pie fillings. In this study, storage at refrigeration temperature had resulted in lower values of % transmittance than those stored at room temperature. Lower transmittance might have resulted due to the formation of more retrograded starch thus culminating in lowered paste clarity. Storage time is also responsible for this low transmittance value, most likely due to the increased retrogradation of the sample. All the values of % transmittance of starches at refrigeration temperature had a decreasing trend. The values of % transmittance of native starches (except rice at 72 h) after all durations were observed to differ significantly from each other ($p < 0.05$), while in blends except BPR132, this trend was observed only up to 24 h, later on their % transmittance values did not differ significantly. Potato starch showed highest % transmittance value (9.65) at refrigeration temperature than other starches and their different blends. However, no significant change was observed in % transmittance value at room temperature with storage time. This behavior suggested low tendency of starch to retrograde at room temperature as compared with the starch sample stored at 4°C. The high clarity of potato starch sample is likely due to the covalently bound phosphate groups preventing association by intra or intermolecular bonds (Bello-Perez, Paredes-Lopez, Roger, & Colonna, 1996). The potato had significantly higher ($p < 0.05$) % transmittance than rice and banana starches both at room temperature and refrigerated temperature. Amylose content is also known to influence the clarity of starch paste as lower amylose starches are easily dispersed, increasing transmittance and clarity (Davies, Maryke, Elizma, Ibrahim, & John, 2008). The potato starch with lower amylose content than rice and banana starch showed higher paste clarity and the blend made with higher amount of potato starch (BPR-132) had significantly higher paste clarity than other blends ($p < 0.05$).

3.7. Freeze–thaw stability

The syneresis of starches and their blends indicating their freeze–thaw stability is shown in Figure 5. The water separation or percent syneresis of any starch paste should be increased with increase in freeze–thaw cycles. This is due to re-association of starch chains, which begins with nucleation and is followed by propagation until crystal perfection (Slade & Levine, 1987). The syneresis of the starches and their blends was significantly different from each other ranging from 1.70 to 7.60 ($p < 0.05$).

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Percent syneresis in rice starch decreased significantly with each freeze–thaw cycle. It was found that during these cycles the amylose of rice starch gel had changed from a smooth gel to a rough-textured porous gel with a sponge-like structure that allowed it to reabsorb the separated water. Thus, syneresis was reduced unless this rough-textured gel was pressed to squeeze out the absorbed water. This retrogradation occurred when the rice starch gel was frozen and ice crystal spread within the gel. The values of percent syneresis in first cycle were higher than second cycle in case of native starches and varied significantly (except banana) ($p < 0.05$), while from second to third cycle percent syneresis of native starches except rice starch increased. The percent syneresis after first cycle in rice starch and the blend with its highest proportion was observed to be maximum. The percent syneresis from first to second cycle had a significant decreasing trend and then from second to third cycle increased significantly ($p < 0.05$). The banana starch and blend with highest proportion showed significantly lesser percent syneresis in their respective category ($p < 0.05$). Upon subsequent thawing at a lower temperature (30°C), the ice crystals melted and rough texture with relatively high porosity was obtained. In the first cycle, only a small quantity of rough porous gel was formed and it was not enough to form a spongy structure and thus high syneresis value was observed from the second to third cycle. The quantity of rough-textured gel accumulated sufficiently to form a sponge-like structure (Deetae et al., 2008).

3.8. Pasting properties

The pasting profiles of starches and their blends are depicted in Figure 6 and the values of various pasting properties are given in Table 3. The peak viscosities were in the range of 3,380–6,179 cP, being the lowest for rice starch and highest for potato starch. PV is indicative of water binding capacity and ease with which starch granules are disintegrated and often correlated with final product quality (Thomas & Atwell, 1999). The hot paste viscosity (HPV) ranged from 2,176 cP for rice starch to 4,449 cP for BPR-132, while the cool paste viscosity (CPV) varied from 4,979 cP for banana starch to 6,846 cP for BPR-132. HPV is influenced by the rate of amylose exudation, amylose–lipid complex formation, granule swelling, and competition between exudated amylase and remaining granules for free water, while CPV is largely determined by the retrogradation tendency of the soluble amylose upon cooling (Olkku & Rha, 1978). The breakdown viscosities varied from 824 cP for BPR-213 starch to 1,853 cP for potato starch. The breakdown is caused by disintegration of gelatinized starch granule structure during continued stirring and heating. The difference in breakdown viscosities is related to the difference in rigidity of swollen granules (Rani & Bhattacharya, 1995). The highest setback viscosity was reported for rice starch (2,866 cP) and lowest for potato starch (934 cP). Banana starch showed the highest (78.55°C) and potato showed the lowest (67.05°C) PT among the

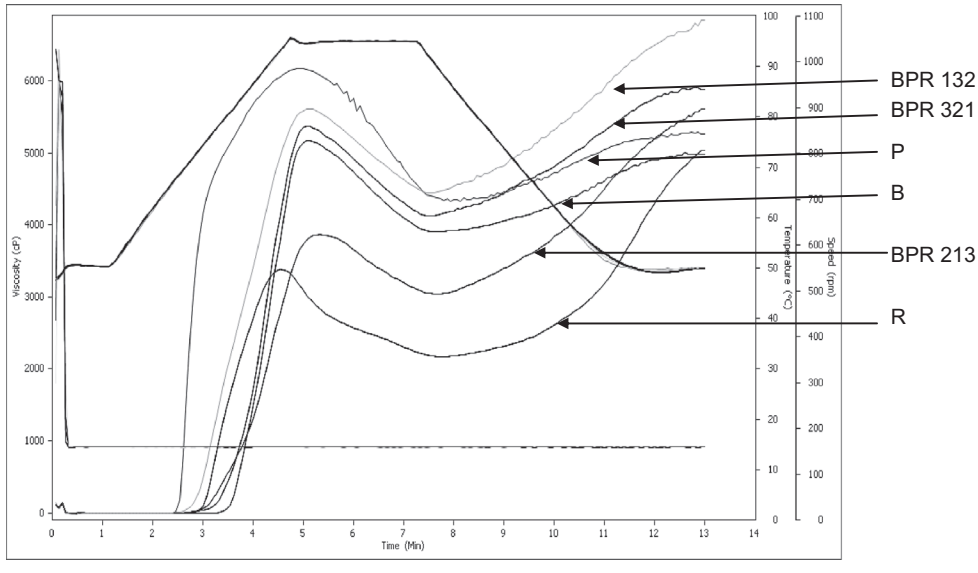

Figure 6. Pasting profiles of native starches and their blends.

Notes: B denotes banana starch; P denotes potato starch; R denotes rice starch; the number 132, 321 and 213 show the ratios of three starches taken in blends in their respective order.

Table 3. Pasting properties of native starches and their blends

Samples	P_{temp} (°C)	PV (cP)	HPV (cP)	BD	CPV (cP)	SB	P_{time} (sec)
B	78.55 ± 1.23^{e}	5,174 ± 5.63^{c}	3,904 ± 5.14^{c}	1,270 ± 1.42^{c}	4,979 ± 6.39^{a}	1,075 ± 5.36^{b}	5.13 ± 0.85^{bc}
P	67.05 ± 0.85^{a}	6,179 ± 10.23^{f}	4,326 ± 6.35^{e}	1,853 ± 2.31^{d}	5,260 ± 7.58^{b}	934 ± 6.58^{a}	4.93 ± 0.23^{b}
R	72.90 ± 0.56^{c}	3,380 ± 12.12^{a}	2,167 ± 3.25^{a}	1,213 ± 1.32^{c}	5,033 ± 5.23^{a}	2,866 ± 4.96	4.53 ± 0.58^{a}
BPR-132	69.55 ± 1.51^{b}	5,613 ± 2.52^{e}	4,449 ± 6.87^{f}	1,164 ± 5.26^{b}	6,846 ± 2.47^{e}	2,397 ± 3.21^{d}	5.13 ± 0.08^{b}
BPR-321	75.25 ± 0.12^{d}	5,377 ± 4.25^{d}	4,120 ± 5.20^{d}	1,257 ± 3.65^{c}	5,887 ± 9.25^{d}	1,767 ± 8.25^{c}	5.07 ± 0.65^{b}
BPR-213	73.8 ± 0.45^{cd}	3,863 ± 9.58^{b}	3,039 ± 2.26^{b}	824 ± 1.10^{a}	5,616 ± 6.35^{c}	2,577 ± 7.53^{e}	5.33 ± 0.47^{c}

Notes: The values are mean ± S.D. of three independent determinations.

The values in a given column with different superscripts are significantly different ($p < 0.05$).

B denotes banana starch; P denotes potato starch; R denotes rice starch.

P_{temp} denotes pasting temperature; P_{time} denotes peak time; PV denotes peak viscosity.

HPV denotes hot paste viscosity; CPV denotes cool paste viscosity; BD denotes break down; SB denotes set back.

The numbers 132, 321 and 213 show the ratios of three starches taken in blends in their respective order.

different starches and their blends. In general, higher PT indicated higher degree of crystallinity (Mishra & Rai, 2006). Potato starch with low amylose content exhibited a pasting profile with lowest PT, the highest PV, and lower setback. However, rice starch having high amylose content had a lowest PV and higher setback. Ritika, Khatkar, and Yadav (2010) also reported similar results for high amylose rice cultivars. High amylose content has been suggested as the major factor contributing to the non-existence of a peak, a high stability during heating, and a high setback during cooling (Lii & Chang, 1981). Synergistic effects were observed in different blends. Blend having highest proportion of potato starch (BPR-132) showed highest value for PV, HPV, and CPV in comparison to other blends. However, blend having highest proportion of rice starch (BPR-213) showed lowest PV, HPV, CPV, and highest value for setback than other blends.

4. Conclusion

This study revealed that the blends of native starches from different botanical sources could be developed to obtain some good functional properties. Synergistic effects could be observed in the functional properties such as swelling power, retrogradation, percent syneresis, freeze–thaw stability and pasting properties of some blends of banana, potato and rice starch. The blend made with higher amount of potato starch (BPR-132) had significantly higher paste clarity than other blends ($p < 0.05$). The banana starch and blend with highest proportion of banana starch showed significantly lesser percent syneresis and thus higher freeze–thaw stability. Blend having highest proportion of potato starch (BPR-132) showed highest value for PV and CPV in comparison to other blends. Thus, it was concluded that it is possible to formulate starch blends from unmodified starches that possess at least some of the desired characteristics of modified starches. However, further characterization of blends is necessary to determine the optimum ratio of starches that best mimics the desired behavior or properties.

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References

Asp, N. G., & Bjorck, I. (1992). Resistant starch. *Trends in Food Science, 3*, 111–114.
Association of Official Analytical Chemists. (1984). *Official methods of analysis* (14th ed.). Arlington, VA: Author.
Bello-Perez, L. A., Meza-Leon, K., Contreras-Ramos, S., & Paredes-Lopez, O. (2001). Functional properties of

corn, banana and potato starch blends. *Acta Cientifica Venezolana, 52*, 62–67.

Bello-Perez, L. A., Paredes-Lopez, O., Roger, P., & Colonna, P. (1996). Amylopectin properties and fine structure. *Journal of Food and Agricultural Chemistry, 56*, 171–176.

Bello-Pérez, L. A., Roger, P., Baud, B., & Colonna, P. (1998). Macromolecular features of starches determined by aqueous high-performance size exclusion chromatography. *Journal of Cereal Science, 27*, 267–278. http://dx.doi.org/10.1006/jcrs.1998.0186

Bello-Pérez, L. A., Romero-Manilla, R., & Paredes-López, O. (2000). Preparation and properties of physically modified banana starch prepared by alcoholic-alkaline treatment. *Starch - Stärke, 52*, 154–159. http://dx.doi.org/10.1002/1521-379X(200006)52:5<154::AID-STAR154>3.0.CO;2-#

Biliaderis, C. G. (1991). The structure and interactions of starch with food constituents. *Canadian Journal of Physiology and Pharmacology, 69*, 60–78. http://dx.doi.org/10.1139/y91-011

Chen, J. J., Lai, V. M.-F., & Lii, C. Y. (2003). Effects of compositional and granular properties on the pasting viscosity of rice starch blends. *Starch - Stärke, 55*, 203–212. http://dx.doi.org/10.1002/star.200390039

Coffmann, G. W. O., & Garcia, V. V. (1977). Functional properties and amino acid content of protein isolate from mung bean flour. *Journal of Food Technology, 12*, 423–477.

Davies, E. M., Maryke, T. L., Elizma, K., Ibrahim, R. M. B., & John, D. K. S. (2008). Some properties of starches from cocoyam (*Colocasia esculenta*) and cassava (*Manihot esculenta Crantz*.) grown in Malawi. *African Journal of Food Science, 2*, 102–111.

Deetae, P., Shobsngob, S., Varanyanond, W., Chinachoti, P., Naivikul, O., & Varavinit, S. (2008). Preparation, pasting properties and freeze thaw stability of dual modified crosslink-phosphorylated rice starch. *Carbohydrate Polymers, 73*, 351–358. http://dx.doi.org/10.1016/j.carbpol.2007.12.004

Feroz, A. J., Khalid, J., & Abid, H. (2004). Extraction of starch from taro (*Colocasia esculenta*) by freeze–thaw method. *Pakistan Journal of Food Science, 14*(1–2), 1–8.

Jane, J. L., & Chen, J. F. (1992). Effect of amylose molecular size amylopectin branch chain length on paste properties of starch. *Cereal Chemistry, 69*, 60–65.

Karam, L. B., Grossmann, M. V. E., Silva, R. S. S. F., Ferrero, C., & Zaritzky, N. E. (2005). Gel textural characteristics of corn, cassava and yam starch blends: A mixture surface response methodology approach. *Starch - Stärke, 57*, 62–70. http://dx.doi.org/10.1002/(ISSN)1521-379X

Kayisu, K., Hood, L. F., & Vansoest, P. J. (1981). Characterization of starch and fiber of banana fruit. *Journal of Food Science, 46*, 1885–1890. http://dx.doi.org/10.1111/jfds.1981.46.issue-6

Kim, Y. S., Wiesenborn, D. P., Orr, P. H., & Grant, L. A. (1995). Screening potato starch for novel properties using differential scanning calorimetry. *Journal of Food Science, 60*, 1060–1065. http://dx.doi.org/10.1111/jfds.1995.60.issue-5

Kinsella, J. E. (1979). Functional properties of soy proteins. *Journal of American Oil Chemist Society, 56*, 204–262.

Lauzon, R. D., Shiraishi, K., Yamazaki, M., Sawayama, S., Sugiyama, N., & Kawabata, A. (1995). Physicochemical properties of cocoyam starch. *Food Hydrocolloids, 9*, 77–81. http://dx.doi.org/10.1016/S0268-005X(09)80268-3

Lii, C. Y., & Chang, S. M. (1981). Characterization of red bean (*Phaseolus radiatus* var. *Aurea*) starch and its noodle quality. *Journal of Food Science, 46*, 78–81. http://dx.doi.org/10.1111/jfds.1981.46.issue-1

Lin, Y. P., Aboubacar, A., Zehr, B. E., & Hamaker, B. R. (2002). Corn dry-milled grit and flour fractions exhibit differences in amylopectin fine structure and gel texture. *Cereal Chemistry, 79*, 354–358. http://dx.doi.org/10.1094/CCHEM.2002.79.3.354

Mishra, S., & Rai, T. (2006). Morphology and functional properties of corn, potato and tapioca starches. *Food Hydrocolloids, 20*, 557–566.

Obanni, M., & Bemiller, J. N. (1997). Properties of some starch blends. *Cereal Chemistry, 74*, 431–436. http://dx.doi.org/10.1094/CCHEM.1997.74.4.431

Olkku, J., & Rha, C. (1978). Gelatinisation of starch and wheat flour starch—A review. *Food Chemistry, 3*, 293–317. http://dx.doi.org/10.1016/0308-8146(78)90037-7

Ortega-Ojeda, F. E., & Eliasson, A. C. (2001). Gelatinisation and retrogradation behaviour of some starch mixtures. *Starch - Stärke, 53*, 520–529. http://dx.doi.org/10.1002/1521-379X(200110)53:10<520::AID-STAR520>3.0.CO;2-D

Peshin, A. (2001). Characterization of starch of isolated from potato tubers (*Solanum tuberosum* L.). *Journal of Food Science and Technology, 38*, 444–449.

Raina, C. S., Singh, S., Bawa, A. S., & Saxena, D. C. (2005). Textural characteristics of pasta made from rice flour supplemented with proteins and hydrocolloids. *Journal of Texture Studies, 36*, 402–420. http://dx.doi.org/10.1111/jts.2005.36.issue-4

Rani, M., & Bhattacharya, K. R. (1995). Rheology of rice-flour pastes: Relationship of paste breakdown to rice quality, and a simplified brabender viscograph test. *Journal of Texture Studies, 26*, 587–598. http://dx.doi.org/10.1111/jts.1995.26.issue-5

Ritika, B. Y., Khatkar, B. S., & Yadav, B. S. (2010). Physicochemical, morphological, thermal and pasting properties of starches isolated from rice cultivars grown in India. *International Journal of Food Properties, 13*, 1339–1354. http://dx.doi.org/10.1080/10942910903131407

Sasaki, T., & Matsuki, J. (1998). Effect of wheat starch structure on swelling power. *Cereal Chemistry, 75*, 525–529. http://dx.doi.org/10.1094/CCHEM.1998.75.4.525

Slade, L., & Levine, H. (1987). Recent advances in starch retrogradation. In S. S. Stivala, V. Crescenzi, & I. C. M. Dea (Eds.), *Recent development in industrial polysaccharides* (pp. 387–430). New York, NY: Gordon and Breach.

Smith, R. J. (1982). Characterization and analysis of starches. In R. L. Whistler & E. F. Paschall (Eds.), *Starch chemistry and technology* (pp. 620–625). New York, NY: Academic Press.

Sosulski, F. W., Garratt, M. O., & Slinkard, A. E. (1976). Functional properties of ten legume flours. *International Journal of Food Science and Technology, 9*, 66–69.

Stute, R., & Kern, H. (1994). Starch mixtures as pudding starches. *U.S. Patent, 5*, 324–532.

Swinkels, J. J. M. (1985). Sources of starch, its chemistry and physics. In G. M. Van Beynum & J. A. Roel (Eds.), *Starch conversion technology* (pp. 15–46). New York, NY: Marcel Dekker.

Takizawa, F. F., Silva, G. O., Konkel, F. E., & Demiate, I. M. (2004). Characterization of tropical starches modified with potassium permanganate and lactic acid. *Brazilian Archives of Biology and Technology, 47*, 921–931.

Thomas, D. J., & Atwell, W. A. (Eds.). (1999). Gelatinization, pasting and retrogradation. In *Starches practical guides for the food industry* (pp. 25–29). St Paul, MN: Eagen Press.

Voutsinas, L. P., & Nakai, S. (1983). A simple turbidimetric method for determining the fat binding capacity of proteins. *Journal of Agricultural and Food Chemistry, 31*, 58–63. http://dx.doi.org/10.1021/jf00115a015

Whistler, R. L., & Paschall, E. F. (1965). *Starch chemistry and technology* (Vol. 1). New York, NY: Academic Press.

Williams, P. C., Kuzina, F. D., & Hlynka, I. (1970). A rapid calorimetric procedure for estimating amylose content of starches and flours. *Cereal Chemistry, 47*, 411–420.

Yadav, B. S., Yadav, R. B., & Kumar, M. (2011). Suitability of pigeon pea and rice starches and their blends for noodle making. *LWT - Food Science and Technology, 44*, 1415–1421. http://dx.doi.org/10.1016/j.lwt.2011.01.004

Zhu, F., & Corke, H. (2011). Gelatinization, pasting, and gelling properties of sweetpotato and wheat starch blends. *Cereal Chemistry, 88*, 302–309. http://dx.doi.org/10.1094/CCHEM-10-10-0145

Zhang, Y., Gu, Z., Hong, Y., Li, Z., & Cheng, L. (2011). Pasting and rheologic properties of potato starch and maize starch mixtures. *Starch - Stärke, 63*, 11–16. http://dx.doi.org/10.1002/star.v63.1