



Extrusion Processing of Restructured Peach and Peach/Starch Gels

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This study investigated the potential of twin screw extrusion technology to produce value-added, restructured peach and peach/starch gels. The effects of water content, melt temperature, sugar and starch concentration on product color, water activity and texture were determined. Water exhibited the greatest effects. As water content increased, product color darkened significantly, water activity increased, and hardness and springiness values decreased significantly in both peach and peach/starch gels. Increasing melt temperatures resulted in darker products. Significant interactions between water content and temperature were observed for 100% peach gels. Starch addition resulted in significant increases in hardness, adhesiveness and cohesiveness values, as well as decreases in product springiness. Increasing melt temperatures resulted in peach/starch gels with softer, more adhesive and cohesive textures. The addition of sugar to peach gels did not significantly affect their color; however, sugar addition did significantly increase the L, a and b values of peach/starch gels. Sugar concentration did not affect peach gel texture, but sugar and starch concentration interacted significantly in peach/starch gels. As sugar concentration increased, the effect of starch concentration on the hardness and adhesiveness decreased. Polynomial regression analysis was utilized to model the relationship between specific mechanical energy and product hardness.

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Introduction

Few studies have investigated extrusion as a means of forming restructured fruit products. Moore (1) and Rapaille (2) refer to extrusion technology as an effective alternative to traditional liquid depositing of confectionery jelly materials containing up to 50% fruit. Maga and Kim (3) evaluated the influence of type and amount of dried fruit and fruit juice concentrate on extruded snack products. Final products containing 10–20% dried fruit and 3.5–7% juice were produced using a single screw extruder. Lugay *et al.* (4) patented an extrusion process for making simulated fruit pieces to be utilized as ingredients in dried food products such as cereals. Recently, a novel combined process utilizing drum drying in combination with twin screw extrusion was developed to produce up to 100% fruit products (5). The rheological properties of peach puree during extrusion were recently evaluated as well (6).

Successful use of extrusion technology for development of novel restructured fruit products requires an understanding of the influence of process conditions and composition on the textural, quality and storage parameters of the final products. Most research has focused on pure

starch gels containing no fruit however. Numerous reviews have been published examining the influence of extrusion on the properties of starch. Twin screw extrusion was evaluated as a bioreactor for starch processing in one such review (7). Another review examined the influence of extruder design and operation on transformations of starch materials (8). Moisture and temperature exhibited the greatest effects on the properties of starch systems (9). At water contents below 200 g/kg, physical cleavage of glycosidic linkages in starch molecules predominates, whereas, gelatinization predominates at moisture contents above 200 g/kg (10).

One of the most highly-valued instrumental techniques for simultaneous measurement of various textural parameters is instrumental texture profile analysis (TPA) (11). The technique was developed in the 1960s when General Foods (Tarrytown, NY, U.S.A.) developed the texturometer (12), capable of compressing foods in a cyclic manner similar to the action of the jaw, portraying the entire force-time history for the test. In recent years, increased use of TPA has occurred with the development of increasingly affordable computer controlled force vs. displacement instruments (13). TPA testing has been applied to a variety of food systems, including high amylose

corn starch gels (13), peaches (14), pears (15) and nuts (16). Sensory results have frequently correlated well with TPA results (16, 17). Currently there is no published TPA data on restructured fruit or fruit/starch gels.

This study applied twin-screw extrusion technology to the production of novel restructured peach and peach/starch gels, containing up to 100% fruit. The objective of the study was to evaluate the effects of moisture content, melt temperature and sugar concentration on physical properties of the product, such as color, water activity and texture. Relationships between specific mechanical energy and product hardness were also examined.

Materials and Methods

Materials

Yellow cling peach puree concentrate (32° Brix) was obtained from Sabroso Company (Medford, OR, U.S.A.). National Starch and Specialty Chemical Company (Bridgewater, NJ, U.S.A.) provided the high amylose corn starch (Ultra-Set LT). Corn syrup (62 DE) was obtained from Liquid Sugars Inc. (Emeryville, CA, U.S.A.) and sucrose cane sugar from Town House (Oakland, CA, U.S.A.). Two sugar solutions were premixed containing 200 g/L (100 g corn syrup plus 100 g sucrose/L solution) or 625 g/L (375 g corn syrup plus 250 g sucrose/L solution).

Feed preparation

Cling peach puree was drum dried to approximately 6% moisture on a Buflovak double drum drier (Buffalo, NY, U.S.A.) at 134°C, 0.6 rpm with a gap width of 0.381 mm. The process of drum drying as a precursor to extrusion was used to enable the formation of 100% fruit snacks and is the subject of a recent patent application (5). Drum dried puree was ground in a Cuisinart food processor (East Windsor, NJ, U.S.A.), then sieved through a Number 45 U.S. standard testing sieve (opening 0.355 mm). High amylose corn starch was then added to the ground puree at three concentrations of 0 g/kg, 150 g/kg and 250 g/kg and the dry mixture was hydrated with approximately 2.5 g/kg distilled water while stirring in a KitchenAid mixer (St Joseph, MI, U.S.A.). The batch size for each treatment was 1.5 kg. Each batch was allowed to equilibrate for at least 12 h at refrigeration temperatures. The procedure used for the preparation of dry feed materials was developed to enable reliable gravimetric feeding of the extruder. Inadequate removal of fines resulted in bridging in the extruder feed section. Excessive moisture in the dry feed mixture resulted in accumulation of material on the initial screw elements with subsequent bridging of the screws in the feed section of the barrel.

Extrusion conditions

A Leistritz (Sommerville, NJ, U.S.A.) co-rotating twin screw extruder was driven by a Haake (Paramus, NJ, U.S.A.) Rheocord 90 computer controlled torque

Table 1 Screw configuration

Screw element description ^a	Section length (mm)	Pitch (mm) or stagger (°)
Spacer	5	–
Feed forward	90	30 mm
Feed forward	30	15 mm
Feed forward	30	10 mm
Spacer	5	–
Four disc forwarding kneading block	20	60°
Spacer	5	–
Feed screw	90	20 mm
Feed screw	60	15 mm
Spacer	5	–
Four disc forwarding kneading block	20	60°
Four disc neutral kneading block	20	90°
Spacer	5	–
Feed forward	90	20 mm
Spacer	5	–
Feed forward	60	10 mm

^a All screw elements are bilobal or double flighted

rheometer. The screw diameter was 18 mm and the screw configuration is shown in **Table 1**. Screw speed was set at 150 rpm. The extruder contained six barrel sections, each with an L:D ratio of 5:1. Dry peach feed mixtures containing three starch concentrations of 0 g/kg, 150 g/kg or 250 g/kg were gravimetrically fed into the first barrel section of the extruder using a K-Tron K2V-T20 feeder (Pitnam, NJ, U.S.A.) at 20 g/min \pm 0.5 g/min. The temperature of this barrel section was not controlled. The remaining five barrel sections and the die adapter were electrically heated and air cooled to maintain two different temperature profiles of 60, 65, 65, 65, 50, 30°C or 60, 95, 105, 95, 40, 40°C, with the first temperature corresponding to the second barrel section and the last to the die adapter. These process temperature regimes were chosen to produce gels containing ungelatinized and gelatinized starch as confirmed by microscopic analyses.

Water or sugar solution (200 g/L or 625 g/L) was metered into the second barrel section at three pump settings (10, 12.5 and 15) using a Bran and Luebbe N-P32 metering pump (Buffalo Grove, IL, U.S.A.). Measured product moisture contents, rather than calculated values, were used for analyses to accurately access effects of moisture content on product properties.

Melt temperatures were monitored to within one degree Celsius in the final barrel section using a J-type thermocouple (Haake Instruments, Paramus). Die melt pressures and melt temperatures were monitored using a Sensatron 1454-73 pressure/temperature probe (Huntington Beach, CA, U.S.A.). Barrel temperatures, melt temperatures, melt pressures, screw speeds and torque values were measured every 6 s using the Rheocord 90 system.

The mixtures were extruded through a 10 mm diameter cylindrical die onto a conveyor belt where they were air

cooled at room temperature. Cooled samples were immediately packaged in aluminum foil and stored at room temperature until testing. All extrusion runs were performed in duplicate.

Microscopy

The presence or absence of birefringence was observed using a Nikon Labophot-2 (Melville, NY, U.S.A.) to determine whether the starch was completely gelatinized. Two grams of extruded samples were diluted with 18 g deionized water. Dilute samples were then placed on slides and observed at 400 \times magnification under a polarizing light microscope. Triplicate measurements were observed for each sample.

Moisture content and water activity tests

Final product moisture content was measured within 4 h of the extrusion run using AOAC official method 22.012. Averages of three measured moisture contents were used for analysis of variance results. Water activity was determined using a Aqualab CX2 meter at 23 $^{\circ}$ C (Decagon Devices Inc., Pullman, WA, U.S.A.) within 4 h of the extrusion run. Samples were ground before testing. Three measurements were performed on each sample.

Colorimeter measurements

A Minolta CR-200 colorimeter (Ramsey, NJ, U.S.A.) was set to measure the Judd-Hunter Lab solid color values (18) within 4 h of the extrusion run. A standard white calibration plate was used to calibrate the colorimeter. Three measurements of intact cylindrical samples (10 mm in diameter and 15 mm in length) were taken at three locations for each sample, making a total of nine measurements per sample.

Texture profile evaluations

An Instron 4502 (Canton, MA, U.S.A.) was utilized to analyse the texture profile of the peach and peach/starch gels 24 h after extrusion. Gels were cut into 15 mm long cylinders with 10 mm diameters and compressed at 12 mm/min to 80% of their original height. Two compression cycles were performed and force, time and distance measurements were recorded every 6 s. The data was analysed as described by Bourne (19) for hardness, springiness, adhesiveness and cohesiveness, and measurements expressed as texture profile values. Triplicate measurements were made for each gel piece.

Specific mechanical energy calculations

Raw torque data was smoothed using a five point sliding boxcar averaging method (20). Specific mechanical energy (SME) values were calculated using Equation 1 after smoothing the raw torque data.

$$\text{SME} = \frac{(\text{Torque})(\text{Screw Speed})}{(\text{Feed Rate})} \quad (\text{Eq. 1})$$

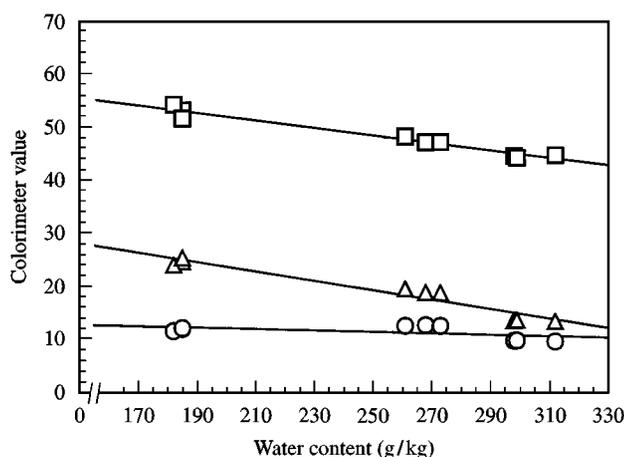


Fig. 1 The influence of water content on the color of extruded 100% peach gels. \square , L; \circ , a; \triangle , b)

Statistical analysis

A three factor factorial design was employed to examine the effects of moisture content, sugar concentration and process temperature on the properties of peach gels. Similarly, a three factor factorial design was utilized to determine the effects of starch concentration, sugar concentration and process temperature on the properties of 26% moisture peach/starch gels. Effects of moisture content on peach/starch gels were analysed using a one factor analysis of variance. ANOVA and Fisher LSD analyses were performed using SuperANOVA at $P < 0.01$ (Abacus Concepts, Berkeley, CA, U.S.A.). Polynomial regression analysis of specific mechanical energy and hardness data was performed using Statview at $P < 0.01$ (Abacus Concepts).

Results and Discussion

Peach gel properties

Moisture content exhibited the greatest effect on all product properties. The first quality impact by which the consumer makes his or her decision to buy a product is based on visual appearance; therefore, product color is of importance. **Figure 1** demonstrates the effect of moisture on the colorimetric properties of extruded peach gels. As moisture content increased, product lightness (L), redness (+ a) and yellowness (+ b) values decreased significantly at $P < 0.01$. Lower moisture content gels exhibited a brighter orange color than higher moisture gels within the range of moistures tested. Previous research has shown that L values of peach gels correlate well with ranks determined using the human eye (21). Product developers can utilize this information to optimize final product color. Similar effects were observed for nonextruded mixtures of dried peach puree and water. These color differences are hypothesized to be characteristic of peach puree/water mixtures of differing moisture contents, rather than the result of differences in browning during processing.

Water activity affects food stability (22). Ideally complete sorption isotherms should be developed for these peach

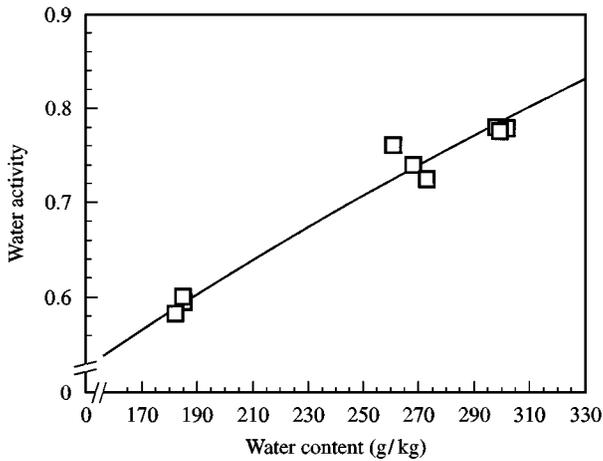


Fig. 2 The relationship between water content and water activity of extruded 100% peach gels

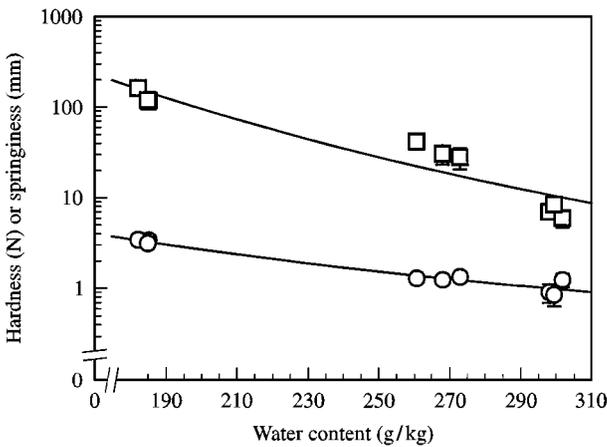


Fig. 3 The influence of water content on the hardness, N (\square) and springiness, mm (\circ) of extruded 100% peach gels

products, however, for the purposes of this study, water activity values were measured under ambient conditions for all extruded gels. The relationship between moisture content and water activity of extruded peach gels was evaluated (**Fig. 2**). As expected, water activity values decreased significantly as product moisture content decreased. Water activity values for these extruded peach products ranged from 0.57 to 0.77.

Moisture content also exhibited significant effects on product texture. Increases in moisture content resulted in significant decreases ($P < 0.01$) in hardness and springiness values (**Fig. 3**) of 100% peach gels. Product adhesiveness and cohesiveness values were not significantly affected by moisture content at $P < 0.01$. Water is known to act as a plasticizer in food systems, therefore, its effect on product texture was anticipated. Texture is a major factor governing food acceptance, therefore, the effects of moisture on gel texture are critical for designing commercial products with desirable mechanical properties.

Changes in the texture profile of ripening peaches were previously examined by Bourne (14). The range of hardness values for ripening peaches, 20–100 N, was similar to the range found in extruded 100% peach gels. Restruc-

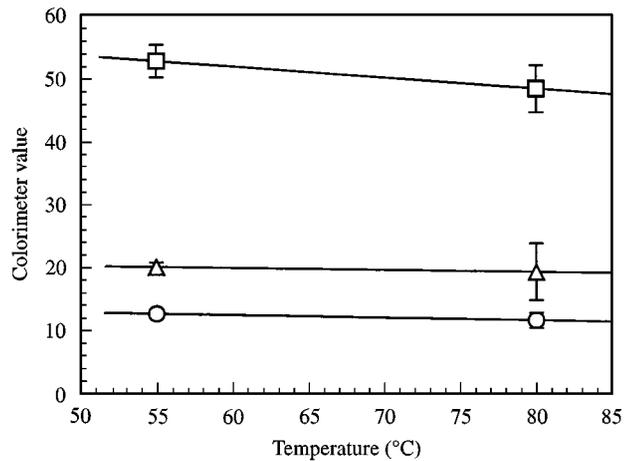


Fig. 4 The influence of melt temperature on the color of extruded 100% peach gels. \square , L; \circ , a; \triangle , b

tured peach gels did not fracture and were adhesive, whereas fresh peaches fractured and did not exhibit any adhesiveness. Texture profile characteristics can be utilized to compare properties of fresh *vs.* restructured fruits. Thermal treatment is commonly employed during food processing, however, it can result in considerable deterioration in product color. Various reactions which affect color such as pigment destruction and non enzymatic browning, can occur during heating of fruits (23). Previous research has been performed on the effect of temperature on the thermal degradation of color in peach puree (24). Decreases in L and b were observed with increases in process temperatures. These color changes were attributed to carotenoid degradation and non enzymatic browning. In this study, higher melt temperatures (80°C) resulted in increased browning of extruded peach gels as evidenced by significant decreases in L, a and b values (**Fig. 4**).

The mechanical properties of concentrated peach gels have not been previously investigated; however, the rheological properties of peach purees have been shown to exhibit Hershel–Buckley flow behavior (25). Over a temperature range of 10–55°C and a soluble solids range of 26–51°Brix, increases in temperature and soluble solids significantly decreased the consistency coefficient of the puree. Temperature was shown to exert little influence on the flow index but significantly affect the yield stress of peach puree. While these studies investigated rheological rather than mechanical properties of peach purees, they indicate that temperature may play a role in modifying product mechanical properties. Surprisingly, temperature did not result in any significant changes in the texture profile of extruded 100% peach gels.

Interactions between moisture content and temperature significantly affected product color, but not water activity or texture. **Figure 5** illustrates the effect of this interaction on L and b values. As process temperature increased, L decreased significantly at all moisture contents. In higher moisture products, this decrease was greater. Product yellowness values increased significantly as temperature increased for lower moisture (18%) products. In

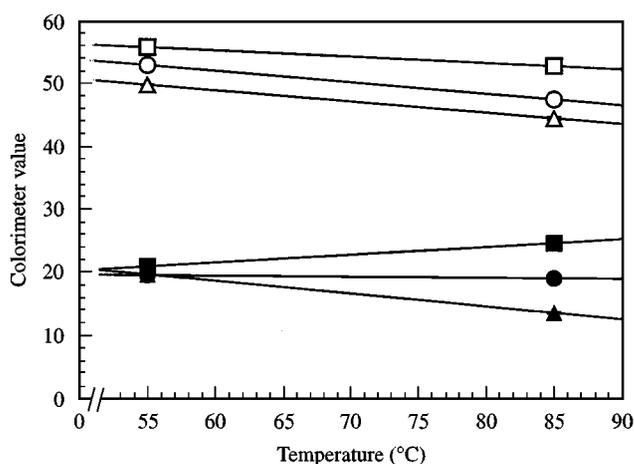


Fig. 5 Effect of interactions between water content and temperature on color □, 180 g/kg water L; ○, 270 g/kg water L; △, 300 g/kg water L; ■, 180 g/kg water b; ●, 270 g/kg water b; ▲, 300 g/kg water b of extruded peach gels

higher moisture (30%) products, however, *b* values decreased significantly as temperature increased. Knowledge of effects of interactions such as this on product color is essential for the development of final products possessing optimal color characteristics. No other significant interactions were observed.

Effects of sugar addition on the properties of extruded 100% peach gels were also examined. Calvo and Duran (21) observed little effect of sugar on the lightness of peach gels containing locust bean and xanthan gum as gelling agents. In equivalent moisture products, addition of sugar solution did not result in any significant ($P < 0.01$) changes in the color of 100% peach gels.

Sugar incorporation has been shown to reduce consistency in fruit products due to the partial alteration of the pectin system (26). The major pectin in peach puree is protopectin, which forms an insoluble macromolecular complex where individual pectin chains are crosslinked with water in the interstices of its reticular macromolecule (26). Changes in fruit rheology were once again not indicative of changes in the peach gel texture. In equivalent moisture products, addition of sugar solution did not result in any significant ($P < 0.01$) changes in product texture profile.

These results suggest that fruit purees could potentially be used as sucrose substitutes in shelf-stable fruit gels without affecting final product color, water activity or texture (27). This offers numerous opportunities for the development of novel, nutritious snack products.

Peach/starch gel properties

Moisture affected the properties of peach/starch gels in the same manner it affected the properties of 100% peach gels. As was observed for 100% peach gels, moisture content significantly influenced all product properties. Increasing moisture contents resulted in significant decreases in product *L*, *a* and *b* values. Water activity values ranged from 0.60 to 0.78 for peach/starch gels. Values increased as product moisture content increased.

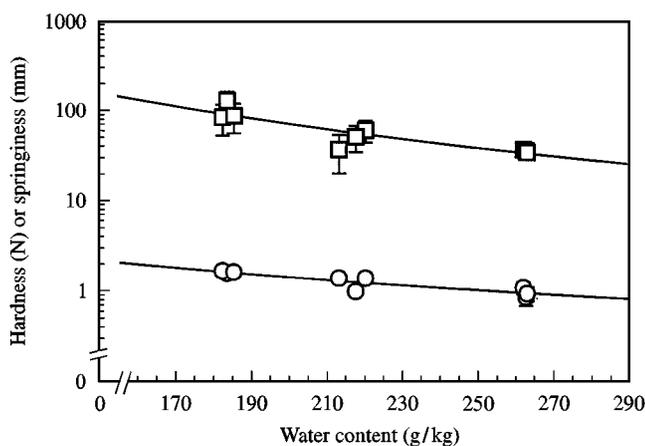


Fig. 6 The influence of moisture content on the hardness, N (□) and springiness, mm (○) of peach/starch gels containing 250 g/kg starch processed at 55°C

As gel moisture content increased, product hardness and springiness values decreased significantly ($P < 0.01$) (Fig. 6). Edwards *et al.* (13) also observed that increases in water content of starch gels resulted in significant decreases in hardness and springiness values in starch gels. The adhesiveness and cohesiveness of the peach/starch gels did not change significantly as the product moisture content varied. These results emphasize the importance of controlling product moisture content as a means to optimize final product properties such as color, water activity and texture. Due to the strong influence of moisture content on all gel properties, the moisture content of the peach/starch gels examined in the remainder of this study was controlled at 26%.

A modified high amylose corn starch was chosen for its easy-to-cook and quick setting properties (28). This starch also imparts a low, hot viscosity, reducing the mechanical energy required to extrude the product. Increasing the concentration of starch in the mixture led to more rapidly setting gels upon exiting the extruder. The effects of starch concentration on product color, water activity and texture profile were examined.

It was hypothesized that starch addition would lighten the color of peach gels since the starch itself is light in color and the peach content of the gels was lessened by the addition of starch. Previous studies by Maga and Kim (3) found that the addition of increasing amounts of dried fruit to an expanded rice product reduced overall *L* values and increased *a* values. The addition of citric acid was used to further increase the lightness in these products. Surprisingly, no significant change in the peach gel color (*L*, *a* or *b*) was observed in this study, as starch concentrations increased from 0 g/kg to 250 g/kg. The orange peach color of the gel must have masked any minor contributions of the starch. Furthermore, it was hypothesized that the starch hydration within the gel reduced its whiteness, thereby eliminating any effects on final product color. Similarly, in equivalent moisture products, the addition of starch had no significant effect on water activity values.

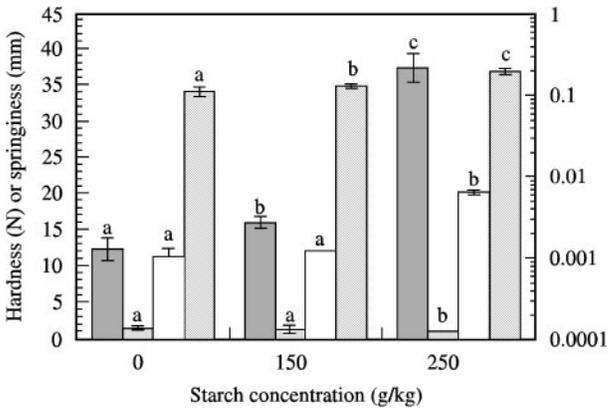


Fig. 7 Effect of starch addition on the texture (■, hardness N; □, springiness mm; □, adhesiveness J; □, cohesiveness) of 260 g/kg water extruded peach gels. Bars, representing the same texture parameter, with different letters above them (a,b,c) are significantly different at $P < 0.01$ using Fisher's PLSD multiple comparison test

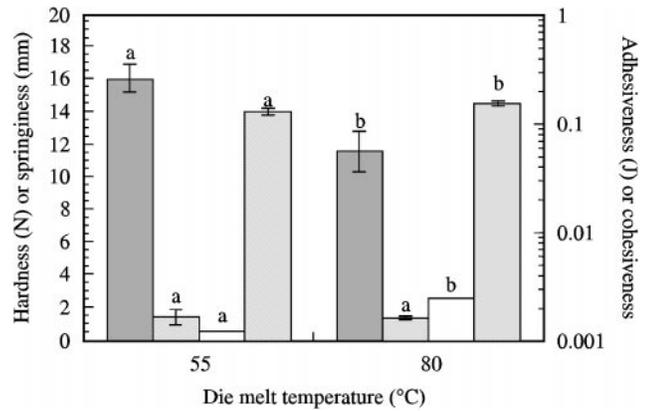


Fig. 8 Temperature effects on the texture (■, hardness N; □, springiness mm; □, adhesiveness J; □, cohesiveness) of 260 g/kg water extruded peach/starch gels containing 150 g/kg starch. Bars, representing the same texture parameter, with different letters above them (a,b) are significantly different at $P < 0.01$ using Fisher's PLSD multiple comparison test

Product texture was modified as starch concentration increased in peach/starch gels. Product hardness, adhesiveness and cohesiveness values increased significantly ($P < 0.01$) with increasing concentrations of starch, whereas product springiness decreased significantly (Fig. 7). It is well known that gel strength increases with starch concentration (29). If one were to equate hardness with gel strength then these results would be consistent with this conclusion. High amylose starch/sucrose gels exhibited hardness values ranging from 16 to 157 N, springiness values ranging from 0.3 to 0.76, adhesiveness values ranging from 0.00002 to 0.02 J and cohesiveness values ranging from 0.13 to 0.26 (13). The peach/starch gels examined in this study were softer and more springy, yet similar in their adhesive and cohesive properties to the high amylose starch/sucrose gels examined previously.

The major changes occurring in starch during the extrusion process are the disruption of the crystalline regions in the granule followed by the loss of granule integrity. Polarizing light microscopy is commonly used to observe these changes. The loss of crystallinity is termed gelatinization and is evidenced by the disappearance of birefringence (7). Temperature and moisture content have been found to exhibit the greatest effects on starch gelatinization during extrusion (9). Typically, when starch is gelatinized by conventional cooking processes, a minimum water content of 35% is necessary, however, under extrusion conditions, gelatinization occurs at moisture levels as low as 10% (7). At moisture contents below 20%, starch fragmentation predominates as the mechanism for gelatinization in twin screw extrusion of high amylose starches (30). The effect of melt temperature on the starch structure in 26% moisture peach/starch gels was examined using polarizing light microscopy. At 80°C the starch was completely gelatinized as evidenced by the complete loss of birefringence. At a die melt temperature of 55°C the starch remained ungelatinized, retaining its birefringence and acting as a filler in the final product. Thermal effects on product color were similar to those

observed with 100% peach gels. Peach/starch gels processed at elevated temperatures (80°C) exhibited significantly lower L , a and b values than their low temperature processed counterparts. These color changes were attributed to carotenoid degradation and nonenzymatic browning, as discussed earlier in this manuscript.

Temperature effects on peach/starch gel texture were also examined (Fig. 8). Hardness values were significantly reduced in gels processed at higher melt temperatures. Conversely, adhesiveness and cohesiveness values were significantly greater in products processed at higher temperatures. Springiness was not affected by process temperature. Ungelatinized starch acted as a filler in gels processed at 55°C resulting in harder, but less adhesive and cohesive products than those containing gelatinized starch.

Politz *et al.* (30) observed decreases in product cohesiveness and springiness values of high amylose corn flours with higher process temperatures. Hardness was not significantly affected by temperature in the Politz *et al.* study. At first glance, these results appear to conflict with the observations for peach/starch gels. The extrusion conditions used in the Politz *et al.* study (140–180°C and 12.5–20% moisture), however, differed from those used in our study (55°C and 80°C and 26% moisture). Starch was fully gelatinized in all extruded gels tested in the Politz study while our study investigated the effects of starch in both the ungelatinized and gelatinized state.

The influence of sugar on the color of peach/starch gels was also investigated. In this study, the addition of a 200 g/L sugar solution to 26% moisture peach/starch gels resulted in significant increases in L , a and b values (Fig. 9). Product color improved significantly as L , a and b values increased with the addition of sugar, however, addition of increasing concentrations of sugar solutions (625 g/L) did not result in any further color improvements (Fig. 9).

The addition of sugar to 26% moisture peach/starch gels resulted in significant decreases in gel hardness and adhesiveness values with no significant effect on gel springiness and cohesiveness values (Figs 10, 11). Interaction

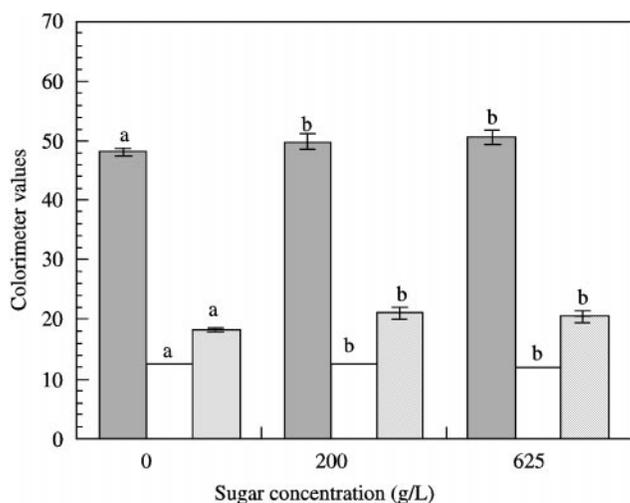


Fig. 9 Effect of sugar addition on the color (■, L; □, a; □, b) of extruded peach/starch gels. Bars, representing a color parameter, with different letters above them (a,b) are significantly different at $P < 0.05$ using Fisher's PLSD multiple comparison test

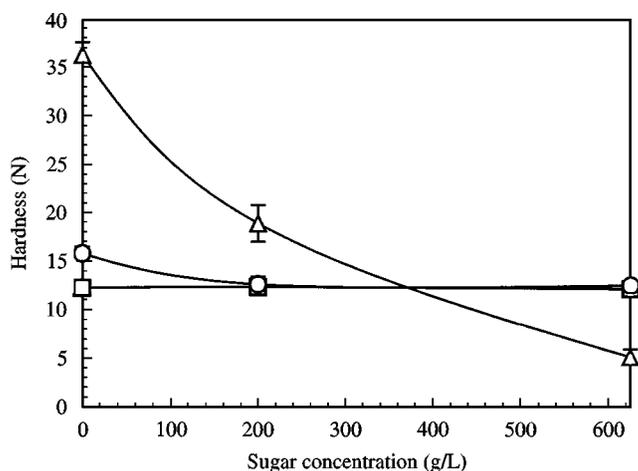


Fig. 10 Interactions between starch concentration (□, 0 g/kg; ○, 150 g/kg; △, 250 g/kg) and sugar concentration on the hardness (N) of peach/starch gels

between sugar concentration and starch concentration on product hardness and adhesiveness values was significant (Figs 10, 11). As sucrose concentration increased, the effect of starch concentration on the hardness and adhesiveness of the gels decreased. Sucrose: starch ratio was shown to have a significant effect on the texture profile of high amylose starch gels (13). As the sucrose: starch ratio increased, product hardness values decreased, as was observed in this study with peach/starch gels.

Specific mechanical energy model

Figure 12 demonstrates the relationship between SME and product hardness. As the SME increased, product hardness increased. Using polynomial regression analysis, this relationship was modeled using the equation shown in Fig. 12 ($R^2 = 0.951$). Specific mechanical energy offers potential as an early indicator of product hardness

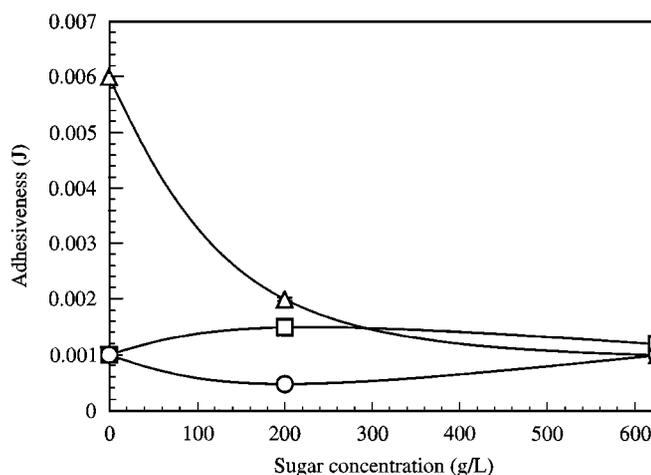


Fig. 11 Interactions between starch concentration (□, 0 g/kg; ○, 150 g/kg; △, 250 g/kg) and sugar concentration on the adhesiveness (J) of peach/starch gels

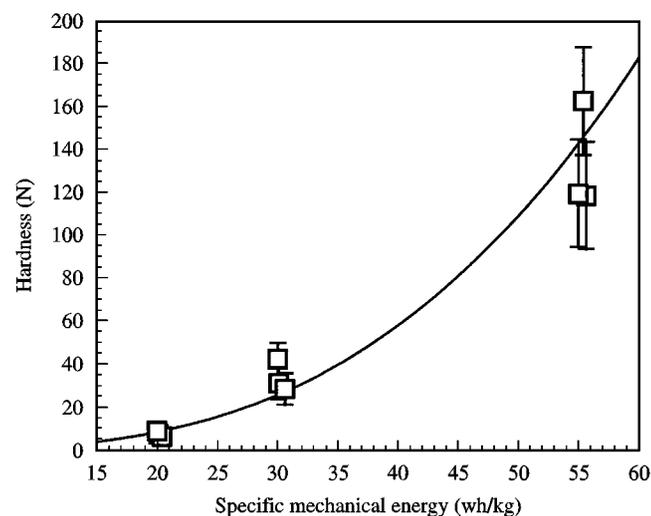


Fig. 12 The relationship between specific mechanical energy and the hardness of extruded 100% peach gels. $f(x) = -21.98 * 0.67 * x * 0.039 * x^2$, $R^2 = 0.951$

enabling the operator to vary process conditions in real time in order to control final product texture.

Conclusions

Up to 100% peach gels can be manufactured using twin screw extrusion technologies. Starch and sugar solutions can be added to these gels to modify physical properties such as water activity, color and texture. Product color can be controlled by limiting melt temperature and moisture content. Product texture can be modified similarly, as well as through the addition of starch. Sugar concentration can be utilized to optimize the color and texture of peach/starch gels, but was shown to have no effect on the properties of 100% peach gels.

Extruded peach and peach/starch gels such as those made in this study could be used as healthy confectionery

alternatives to be eaten out of hand as shelf-stable snacks or as ingredients to be added to baked and frozen food products, such as muffins, cookies and ice cream. These results can be applied to the manufacture of fruit products from other commodities such as strawberries, apricots, pears and apples. This study presented results in terms of texture profile attributes as determined by mechanical tests. Additional studies are needed to relate these results to sensory perceptions.

Acknowledgments

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