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PEACH POMACE PROCESSING USING TWIN SCREW EXTRUSION

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ABSTRACT

Fruit by-products have found limited applications in the food industry. They have been primarily used as animal feed, applied to agricultural land for soil amendment or composted and applied to farms for growing crops. Some of these disposal methods are not environment friendly, while others are costly. This study was undertaken to examine the possibility of utilizing peach pomace as a source of soluble dietary fiber in expanded extruded food products. Peach pomace was combined with rice flour at four different levels. The four blends were mixed, dried to a moisture level of 13.5% (w/w) and ground to flour. These blends were extruded in a twin-screw extruder (Clextral EV-25) at a feed flow rate of 15 kg/h. The extruded products were analyzed for physical and textural properties. The apparent and true densities for the extrudates decreased from 183.93 to 133.94 kg/m^3 and 1275.31 to 1171.2 kg/m^3, respectively. A linear increase in extrudate porosity (85.11-88.54%) and radial expansion ratio (13.5-19.3) and a steady decrease in breaking strength (104-50.74 kPa) were observed with increasing peach pomace level in the blends. This study demonstrates the potential of extrusion processing as a tool for fruit by-product utilization, which will not only enhance consumption of soluble dietary fiber but will also increase the overall fruit utilization.

Keywords: Twin screw extrusion, peach pomace, rice flour

INTRODUCTION

The United States of America is one of the leading peach producing countries. The total production in 2008 was more than 1.13 million tons, of which approximately 1.1 million tons was utilized for human consumption. Only 48% was consumed fresh and the remaining 52% was processed into a variety of peach products (**USDA, 2009**). Processing of peach generates pomace and other solid by-products. Traditionally, these by-products have been used as animal feed, applied to agricultural land as soil amendments, or composted and applied to farms for growing crops. Disposal of highly polluting organic matter creates major environmental and economic problems (**Lowe and Buckmaster, 1995**). Some of these disposal methods are not environmental friendly, while others are costly. Technological developments on the utilization of fruit by-products have been limited. Some studies have reported on the incorporation of fruit (apple, peach, citrus) processing by-products in bakery products (**Wang and Thomas, 1989; Carson *et al*., 1994; Masoodi and Chauhan, 1998; Masoodi *et al*., 2002; Sudha *et al*., 2007**) and meat products (**Grigelmo-Miguel *et al*., 1999; Fernandez-Lopez *et al*., 2004**) with a low level (4-5%) substitution.
Despite high nutritional value, by-products from the fruit processing industry remain largely unused for human consumption. Dietary fiber from fruits is higher in soluble fiber (7-14.1% of total fiber) compared to cereals (0.4-3.6% of total fiber), contains lower level of phytic acid, shows better water and oil holding capacity and exhibits higher fermentation potential by colonic probiotic organisms (**Martin-Cabrejas *et al*., 1995; Grigelmo-Miguel and Martin-Belloso, 1999; Larrauri, 1999; Fernandez-Lopez *et al*., 2004**). While insoluble dietary fiber plays a major role in gastrointestinal control of water absorption and bowel movement (**Kay, 1982; Anderson *et al*., 1994**), soluble fibers are valued for their ability to reduce serum cholesterol level, lower blood pressure and decrease the risks of coronary heart disease and certain types of cancers. The soluble fiber intake for humans should be in the range of 30-50% of total dietary fiber (**Spiller, 1986; Eastwood, 1987**).
Extrusion processing has found widespread application in restructuring fiber rich cereals such as wheat bran, wheat flour and wheat fiber, corn bran and meal, corn fiber, barley flour, oat meal, oat bran and rice bran into a variety of food products (**Siljestrom *et al*., 1986; Hsieh *et al*., 1989; Lue *et al*., 1990; Camire and Flint, 1991; Lue *et al*., 1991; Gualberto *et al*., 1997; Huth *et al*., 2000; Mendonca *et al*., 2000; Vasanathan *et al*., 2002; Yanniotis *et al*., 2007**). However, research on extrusion processing of fruit pomace is sparse. Few extrusion studies have been reported on fruit processing by-products (**Gourgue *et al*., 1994; Hwang *et al*., 1998; Larrea *et al*., 2005**), blends of cereal flours and fruit processing by-products (**Altan *et al*., 2008; Yagci and Gogus, 2008; Altan *et al*., 2009**), and for production of restructured peach, peach-starch gels and peach puree based snack food (**Akdogan and McHugh, 1999; McHugh and Huxsoll, 1999**). In addition some recent research has also focused on extrusion of dietary fiber rich biomaterials (**Repo-Carrasco-Valencia *et al*., 2009; Elleuch *et al*., 2011; Wolf *et al*., 2010; Robin *et al*., 2012**). The objective of our study was an attempt to develop an expanded extruded product with high soluble fiber content by twin-screw extrusion of peach pomace and rice flour blends. The effect of four levels of peach pomace on the physical and textural properties of the rice flour based extrudates was evaluated.

MATERIAL AND METHODS

Materials

Fresh peach pomace was supplied by Wawona Frozen Foods (Clovis, Calif., U.S.A.) and coarse white rice flour was obtained from Pacific Grain Products, Inc. (Woodland, Calif., U.S.A.). Peach pomace was analyzed for moisture, ash, protein and fat content following the standard AOAC procedures (**AOAC, 2000**). Carbohydrate content was calculated by difference. The fiber content of peach pomace was analyzed by Warren Analytical Laboratories (Greeley, Co., U.S.A.). The data on rice flour composition was provided by the supplier. The proximate composition of the materials is listed in Table 1.

Blend Preparation

Four feed blends were prepared by mixing rice flour and peach pomace in a Hobart HCM450 Cutter Mixer (Hobart Corp, Troy, Oh., U.S.A.). The solid ratios (rice flour solids: peach pomace solids) in these four blends were 6:1, 8:1, 10:1 and 12:1. The mixes were then dried using a tray drier (Commercial Dehydrator Systems, Eugene, Ore., U.S.A.) at a temperature of 165°F. Samples were randomly withdrawn during the drying period to analyze moisture content using a CSC Digital Moisture Balance (CSC Scientific Company, Inc., Fairfax, Va., U.S.A.). The drying process was stopped when the moisture content in all four blends reached 13.5% on a total weight basis. The blends were ground to fine particle size using Hobart HCM450 Cutter Mixer and a commercial blender

(Waring Inc., Torrington, Ct, U.S.A.). The blends were analyzed for moisture content just before extrusion using the CSC Digital Moisture Balance. If needed, the moisture level was adjusted by spraying water and slowly mixing the blends in a Varimixer at a minimum speed of 50 rpm (Welbilt, Shreveport, La., U.S.A.). The total, soluble and insoluble dietary fiber levels on a percent dry weight basis in each of the four blends are shown in Table 2.

Extrusion Experiments

The ground mixtures were extruded using EV 25 A108 co-rotating intermeshing twin screw extruder (Clextral, Firminy, France). Feed material was incorporated into the extruder using a feeder (K-Tron Corp., Pitman, N.J., U.S.A.) which was equipped with an agitator to facilitate the movement of the dried mix. The extruder consisted of ten barrel sections. The temperature profile from the feed to the die end of the extruder during experimentation is shown in Figure 1. Monitoring of feed flow rate, screw speed, barrel temperatures, percent torque, die pressure and die temperature was performed using the Programmable Logic Control (PLC) FITSYS + version 2.01 software from a computer installed on the extruder. The extruder screw configuration is shown in Table 3.

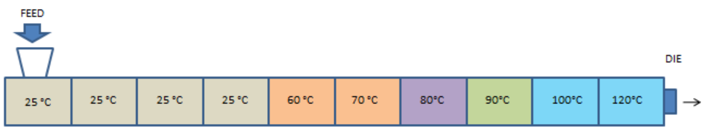

Figure 1 Temperature profile of the extruder used for processing of peach pomace and rice flour blends

Screw speed, feed flow-rate and feed moisture content during extrusion were maintained at 400 rpm, 15 kg/h, and 13.5% (wet basis), respectively. Die diameter and extruder length/diameter ratio were 4.5 mm and 40:1, respectively. Samples in the shape of a cylinder were collected when the extruder attained steady state conditions as indicated by constant percent torque, die pressure and die temperature. Extrudates were stored overnight under ambient conditions (25 ± 1 °C) and evaluated for physical and textural attributes. All results are an average of three extrusion trials.

Experimental design and statistical analysis

A completely randomized experimental design was used to carry out the experiments. Descriptive statistics, correlational analysis, analysis of variance (ANOVA) and comparison of means were performed using SPSS statistical package, version 16.0 (Chicago, Ill., U.S.A.). Graphics were created using the PSI-Plot software, version 9.01 (Poly Software International, NY, U.S.A.). Comparison of means was carried out using Tukey's HSD Multiple Comparison Test, at 95% significance level.

Product Analysis

Densities

Six samples (50-110 mm long) from each trial were selected and weighed. Fifty diameter and ten length readings were taken on each sample using a digital caliper with an accuracy of ± 0.01 mm (General Tools, New York, N.Y., U.S.A.). The readings were averaged, and these average diameters and lengths were used to calculate the following physical characteristics of the extruded samples.

The apparent density was calculated using the following equation (**Choudhury and Gautam, 2003**):

$$Apparent\ Density = \frac{Mass\ of\ Samples\ (Kg)}{Apparent\ Volume\ of\ Samples\ (m^3)}$$

The true density was obtained as the ratio of extrudate mass to the true volume. (**Choudhury and Gautam, 2003**). True volume was measured using a multipycnometer (Quantachrome Instruments, Boynton Beach, Fla., U.S.A.) (Chang 1988). Archimedes Principle is used to estimate true density of the samples. The multipycnometer uses helium gas to penetrate the smallest of the pores within the product with dimensions close to 1 Angstrom (10^{-10}). The reference cell pressure (P_1) used in the study was approximately 17 psig. Reference cell pressure (P_1) and Sample cell pressure (P_2) were recorded. The following equation was used to calculate true volume of the extrudates (**Choudhury and Gautam, 2003**):

$$True\ Volume\ (V_P) = V_C - V_R[\frac{P_1}{P_2} - 1]$$

where, V_p= Sample Volume, V_c= Cell Volume, V_r= Reference Cell Volume, P_1= Reference Cell Pressure (Psig), P_2= Sample Cell Pressure (Psig).

Porosity

The porosity (ε) of the extruded samples was calculated using the following equation:

$$Porosity = \frac{Apparent\ Specific\ Volume - True\ Specific\ Volume}{Apparent\ Specific\ Volume}$$

Expansion Ratios

The radial expansion ratio was measured as the ratio of the cross-sectional area of the extruded sample to the cross-sectional area of the circular extruder die (die diameter: 4.5 mm, die cross-sectional area: 1.589×10^{-5} m^2) (**Bhattacharya and Choudhury, 1994; Choudhury and Gautam, 2003**). The equation for calculating radial expansion ratio is (**Choudhury and Gautam, 2003**):

$$Radial\ Expansion\ Ratio = \frac{Cross-sectional\ Area\ of\ Extrudate}{Cross-sectional\ Area\ of\ Die}$$

The overall expansion ratio was calculated as the ratio of apparent specific volume to true specific volume of the extruded samples (**Sokhey *et al.*, 1996; Kollengode *et al.*, 1996; Hanna *et al.*, 1997; Choudhury and Gautam, 2003**):

$$Overall\ Expansion\ Ratio = \frac{Apparent\ Specific\ Volume}{True\ Specific\ Volume}$$

The axial expansion ratio was obtained as the ratio of overall expansion to the radial expansion (**Sokhey *et al.*, 1996; Kollengode *et al.*, 1996; Hanna *et al.*, 1997; Choudhury and Gautam, 2003**):

$$Axial\ Expansion Ratio = \frac{Overall\ Expansion Ratio}{Radial\ Expansion Ratio}$$

Textural Properties

Breaking strength of the extrudates was determined by using the TA-XT Plus Texture Analyzer (Texture Technologies Corp., Scarsdale, N.Y., U.S.A.). The extrudates were cut using the Warner-Bratzler stainless steel shear probe (probe thickness: 1.00 mm, shear angle: 60°) at a pre-test and test speed of 1.5 mm/sec and post-test speed of 10 mm/sec, respectively. The breaking strength (kPa) was calculated using the following equation (**Maurice and Stanley, 1978; Owusu-Ansah *et al.*, 1984; Bhattacharya *et al.*, 1986; Bhattacharya and Hanna, 1987; Chinnaswamy and Hanna, 1988; Choudhury and Gautam, 2003**):

$$Breaking\ Strength = \frac{Peak\ Force}{Cross-sectional\ Area}$$

The maximum (peak) force required to cut the extrudate into two pieces was obtained from the force-time curve.

Specific mechanical energy

The specific mechanical energy (SME) was calculated from the % torque data obtained from the computer installed on the extruder. The following equation was used to calculate specific mechanical energy values (**Gogoi *et. al.*, 1996**):

$$SME = \frac{Nactual}{Nrated} \times \frac{\%\tau}{100} \times \frac{Prated}{m}$$

Where n is screw speed (rpm), τ is the net torque, P is the motor power (kJ/s), m is the feed rate (kg/s).

RESULTS AND DISCUSSION

Table 1 Proximate composition of peach pomace and rice flour

Constituents	Ingredients	
	Peach pomace (%, wb)	Rice flour (%, wb)
Moisture	85.2	12.89
Protein	0.964	6.61
Fat	0.37	0.58
Ash	0.399	0.58
Carbohydrate	13.06	79.34
Total fiber	7.85	1.18
Soluble fiber	2.60	0.29
Insoluble fiber	5.25	0.89

Table 2 Total, soluble and insoluble dietary fiber levels in the peach pomace and rice flour blends

Rice flour: Peach pomace		Dried batch size (kg)	Rice flour solids (kg)	Peach pomace solids (kg)	Fiber composition of peach pomace (% of total solids)		
Fresh ratio	Solid ratio				Total	Soluble	Insoluble
1:1	6:1	50	37.07	6.18	7.58	2.57	5.06
1.25:1	8:1	50	38.44	4.80	5.88	2.00	3.94
1.5:1	10:1	50	39.32	3.93	4.81	1.64	3.24
1.75:1	12:1	50	39.92	3.33	4.07	1.39	2.73

Table 3 Screw configuration of the twin screw extrusion system used for extruding peach pomace and rice flour blends

Element type	Pitch (mm)	Pitch (× D)	Stagger angle (°)	Length (mm)	Length (× D)	No of elements
Trapezoidal double flights (T2F)[A]	31.25	1.25D	–	31.25	1.25D	4
Conjugated double flights (C2F)	31.25	1.25D	–	31.25	1.25D	8
Conjugated double flights (C2F)	25	1.00D	–	25	1.00D	6
Kneading block (KB)	–	–	90°	25	1.00D	1
Conjugated double flights (C2F)	18.75	0.75D	–	18.75	0.75D	2
Kneading block (KB)	–	–	90°	25	1.00D	1
Kneading block (KB)	–	–	45°	25	1.00D	1
Transition Element (TE)	–	–	–	6.25	0.25D	1
Conjugated single flights (C1F)	12.5	0.50D	–	12.5	0.50D	7
Transition Element (TE)	–	–	–	6.25	0.25D	1
Conjugated double flights (C2F)	18.75	0.75D	–	18.75	0.75D	3
Kneading block (KB)	–	–	90°	25	1.00D	1
Conjugated double flights (C2F)	18.75	0.75D	–	18.75	0.75D	9
Conjugated double flights (C2F)[B]	12.5	0.50D	–	12.5	0.5D	1

[A] Feed end
[B] Die end

Effects of Feed Composition on Specific Mechanical Energy

Feed composition did not show significant effect on specific mechanical energy (SME) during extrusion processing of peach pomace and rice flour blends (Table 4, Figure 2). In a study on extrusion of barley flour and tomato pomace blends, the researchers observed a significant increase in specific mechanical energy with an increase in tomato pomace level in the feed mix (**Altan *et al*., 2008**).This opposite behavior seems to be due to process conditions (feed rate: 2.11 kg/h, screw speed: 150-200 rpm, feed moisture content: 21-22%, wet weight basis), feed constituents (tomato pomace and barley flour), and feed composition (2-10% of tomato pomace level) used by these investigators, which were markedly different from those used in our study. The process parameters and feed composition strongly influence material rheology during extrusion, which in turn affects mechanical energy input.

Specific mechanical energy exhibited a significant positive and negative correlation with apparent density (r= 0.99, F= 101.02) and die temperature (r= -0.98, F=41.12), respectively. **Altan *et al.* (2008)** also reported a positive correlation between SME and apparent density and a significant negative correlation between SME and die temperature. Higher material temperature indicates lower melt viscosity which reduces SME (**Altan *et al*., 2008; Chang *et al*.. 1999; Hsieh *et al*., 1989**). Feed material with lower mechanical energy input produced extrudates with lower apparent density.

Table 4 Analysis of variance (ANOVA) data of the response variables (specific mechanical energy, apparent density, true density, porosity, radial expansion, overall expansion, axial expansion and breaking strength)

Source	DF	SME (kJ/kg)	Apparent density (kg/m^3)	True density (kg/m^3)	Porosity (%)	Radial expansion ratio	Overall expansion ratio	Axial expansion ratio	Breaking strength (kPa)
Feeds solids ratio	3	0.94	29.81*	9.18*	19.8*	73.58*	19.23*	6.12*	168.41**
Error	68	-	-	-	-	-	-	-	-

*Significant at $p \leq 0.05$
**Highly Significant at $p \leq 0.01$

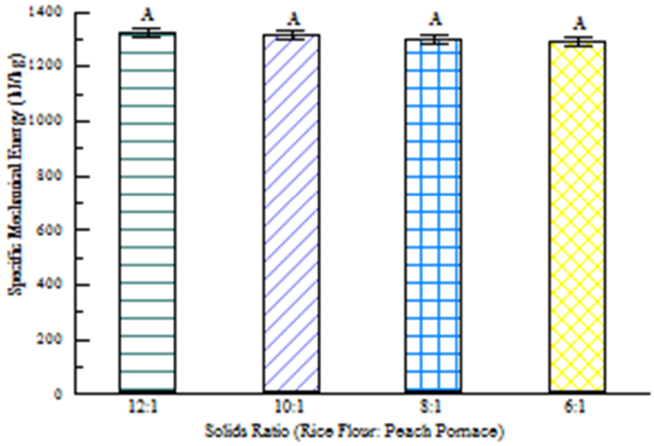

Figure 2 Effects of rice flour and peach pomace solids ratio on the specific mechanical energy of the extrudates. Bars with different letters are significantly different from each other

Effects of Feed Composition on Extrudate Densities

Apparent density

Peach pomace solids affected apparent density of the extrudates significantly ($p \leq 0.05$) (Table 4). Apparent density of the extrudates decreased from 183.893 kg/m^3 to 133.94 kg/m^3 with an increase in peach pomace level (Figure 3). This interesting finding provides us a novel tool to utilize peach pomace as a modifying ingredient in starch based food structures. The decrease in apparent density seems to be due to higher soluble fiber (Table 2) in feed with increasing peach pomace level. Similar trend in bulk density with increasing fruit waste (orange peel, grape seed and tomato pomace) level was explained to be due to the higher pectin (soluble fiber) content in feed with increasing amount of fruit waste (**Yagci and Gogus, 2008**) . **Altan *et al.* (2008)** also reported a decrease in bulk density at a die temperature of 140°C. However, they observed an opposite trend at higher die temperatures, which implies that the effect of pomace level on bulk density is a strong function of temperature.

A strong negative correlation was observed between apparent density of extrudates and die temperature (r= -0.97, F=30.49). This observation is in agreement with the finding of **Altan *et al.* (2008)** who reported an increase in apparent density with a decrease in die temperature during extrusion of tomato pomace and barley flour blends. Similar negative correlation between apparent density and die temperature have also been reported by **Choudhury and Gautam (2003); Bhattacharya and Hanna (1987); Grenus *et al.* (1992); Bhattacharya and Choudhury (1994)**.

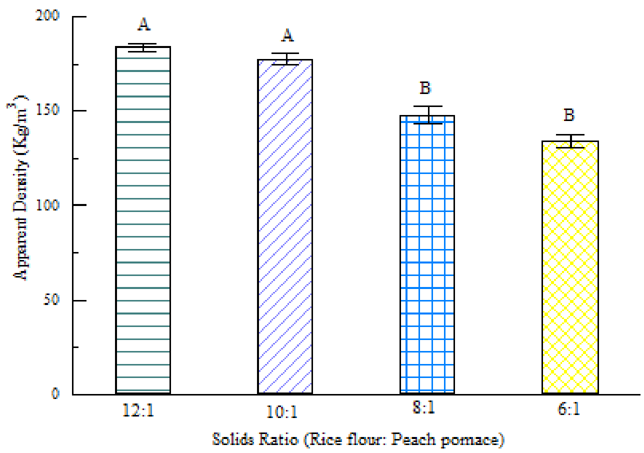

Figure 3 Effects of rice flour and peach pomace solids ratio on the apparent density of the extrudates. Bars with different letters are significantly different from each other

True density

The true density decreased gradually with increasing peach pomace level, a trend similar to that of the apparent density (Figure 4). Adding peach pomace to rice flour had a significant effect on extrudate true density ($p \leq 0.05$) (Table 4). Comparison of means revealed that the true density of extrudate is not significantly affected up to a peach pomace solids level of ~9% (10:1 ratio). However, the true density significantly increased (Figure 4) when peach pomace solids level in the blend was reduced to ~ 7% (12:1 ratio), indicating a dominant effect of rice flour on true density.

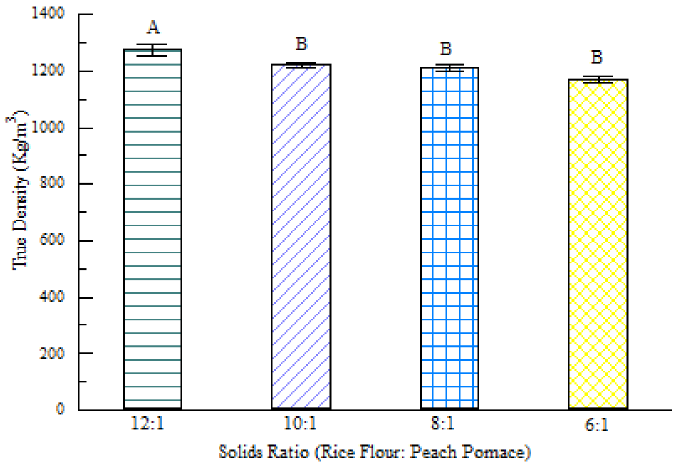

Figure 4 Effects of rice flour and peach pomace solids ratio on the true density of the extrudates. Bars with different letters are significantly different from each other

Effects of Feed Composition on Extrudate Expansion Ratios

Radial expansion ratio

The radial expansion of the extrudates increased with increasing peach pomace level in the feed mix, and the effect of feed composition on radial expansion was significant ($p \leq 0.05$) (Table 4) (Figures 5). Addition of peach pomace increased radial expansion ratio from 13.5 (for feed solids ratio of 12:1) to 19.3 (for feed solids ratio of 6:1). Figure 6 shows the actual images of extruded peach pomace and rice flour blends and the increase in radial expansion ratio with increase in peach pomace levels. An opposite trend was observed with increasing level of tomato pomace, cauliflower by-products, and sugar beet fiber in feed blends with barley, wheat, and corn flours, respectively (**Altan *et al.*, 2008; Stojceska *et al.*, 2008; Lue *et al.*, 1991**). It is difficult to interpret this behavior without compositional data on feed materials. Another study by **Yanniotis *et al.* (2007)** compared the effects of added wheat fiber and pectin on radial expansion of corn starch and observed much higher expansion with added pectin at 5% and 10% level compared to that of wheat fiber addition at the same levels.

Fruits and fruit processing by-products are rich sources of soluble dietary fiber whereas the presence of soluble fiber in cereals is considerably low. For example, the soluble fiber content in peach processing by-product is 9.7 g/100g of dry matter whereas in wheat bran it is 2.9 g/100g of dry matter (**Grigelmo-Miguel and Martin-Belloso, 1999**). Addition of soluble fiber such as pectin to corn starch seems to exhibit a higher radial expansion compared to wheat fiber addition at 5% and 10% level (**Yanniotis *et al.*, 2007**). We also observed an increase in radial expansion with increasing level of soluble fiber (from 1.39% to 2.57%) in our feed blends (Table 2). Further research will be needed to understand the effect of soluble and insoluble fibers on product expansion.

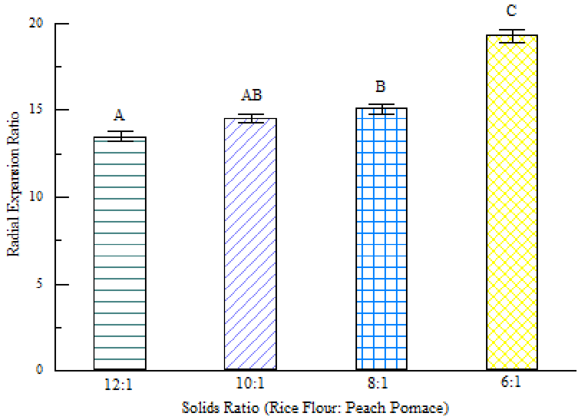

Figure 5 Effects of rice flour and peach pomace solids ratio on the radial expansion ratio of the extrudates. Bars with different letters are significantly different from each other

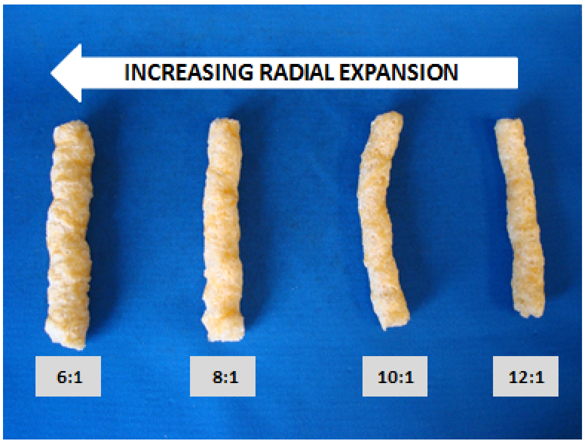

Figure 6 Increase in radial expansion ratio with increase in peach pomace level

Overall expansion ratio

A systematic increase in overall expansion ratio was observed with increasing peach pomace level in feed mix (Figure 7), a trend similar to radial expansion. The effect of peach pomace on overall expansion ratio of the peach pomace and rice flour extrudates was significant ($p \leq 0.05$) (Table 4). Statistical evaluation showed a strong positive correlation between overall expansion ratio and die temperature (r= 0.95, F=19.110). Similar relationship between overall expansion and die temperature was exhibited by **Choudhury and Gautam (2003)**.

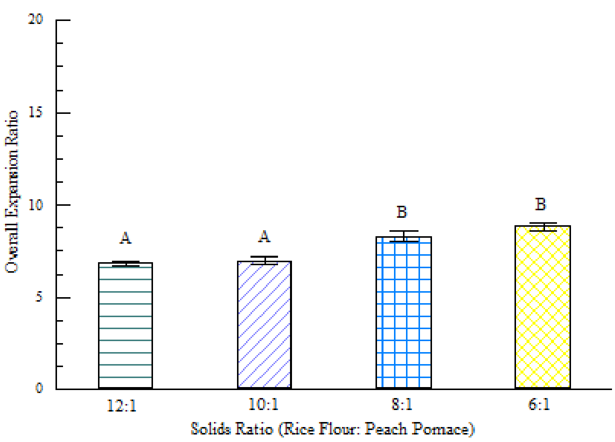

Figure 7 Effects of rice flour and peach pomace solids ratio on the overall expansion ratio of the extrudates. Bars with different letters are significantly different from each other

Axial expansion ratio

The effect of peach pomace on axial expansion ratio was much smaller (Figure 8) compared to that of radial and overall expansion ratios. Although the effect was statistically significant ($p \leq 0.05$) (Table 4), no systematic trend was observed with increasing peach pomace content in the feed mix. The axial expansion ratio generally decreased with increasing peach pomace content from 12:1 to 6:1 ratio except for 8:1 blend where an abrupt increase to 0.55 was observed (Figure 8).

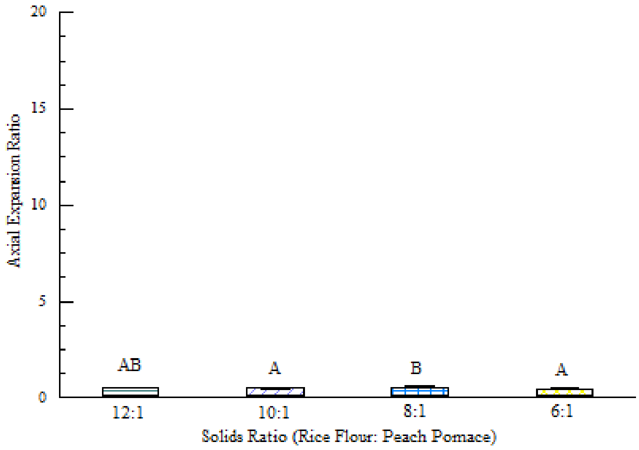

Figure 8 Effects of rice flour and peach pomace solids ratio on the axial expansion ratio of the extrudates. Bars with different letters are significantly different from each other

Effects of Feed Composition on Extrudate Porosity

The extrudates became more porous as the level of peach pomace in the feed mix was increased. Porosity values increased from 85.11% to 88.54% with increasing peach pomace content, from feed solids ratio of 12:1 to 6:1 ratio, and the effect of feed solids ratio on extrudate porosity was significant ($p \leq 0.05$) (Table 4, Figure 9). Our data on extrudate porosity is in agreement with the findings of **Yagci and Gogus (2008)**. They observed higher extrudate porosity as the fruit waste level in the feed mix was increased from 3% to 7%. The higher extrudate porosity with increasing peach pomace level content seems to be due to higher level of soluble fiber in the feed mix. The soluble fiber level increased from 1.39% in the 12:1 mix to 2.57% in the 6:1 mix (Table 2). **Yanniotis *et al.* (2007)** reported a similar effect of pectin (soluble fiber) on extrudate porosity, which increased from 82% to 85% when pectin (soluble fiber) content in the feed mix containing corn starch was raised from 0% to 10%.

A positive linear correlation was observed between porosity and overall expansion ratio (r= 0.99, F=4107.46). A similar relationship was reported by **Choudhury and Gautam (2003)** during twin screw extrusion of hydrolyzed fish muscle and rice flour blends.

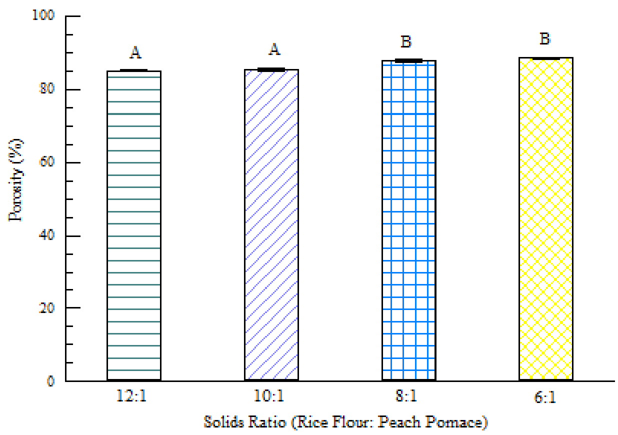

Figure 9 Effects of rice flour and peach pomace solids ratio on the porosity of the extrudates. Bars with different letters are significantly different from each other

Effects of Feed Composition on Extrudate Breaking Strength

The peach pomace level in feed mix showed a highly significant effect on extrudate texture (Table 4). The breaking strength, a textural attribute of the extrudates, decreased systematically from 103.8 kPa to 50.74 kPa with increasing peach pomace level in the feed mix (Figure 10). This decrease in breaking strength seems to be due to higher soluble fiber in the feed mix, which increased from 1.39% in 12:1 mix to 2.57% in 6:1 mix (Table 2). Similar effect of pectin (soluble fiber) was reported by **Yanniotis *et al.* (2007)** who observed a significant decrease in extrudate hardness when pectin concentration in the feed mix containing corn starch was increased from 0% to 10%. **Altan *et al.* (2008)** also observed a decrease in extrudate hardness at a die temperature of 140°C when tomato pomace in feed mix containing barley flour was increased. Breaking strength exhibited a significant negative linear correlation with radial expansion ratio (r= -0.95, F=19.21). A similar relationship between breaking strength and radial expansion has been reported by **Hsieh *et al.* (1990), Hsieh *et al.* (1993), Jin *et al.* (1995), Rinaldi *et al.* (2000) and Choudhury and Gautam (2003)**.

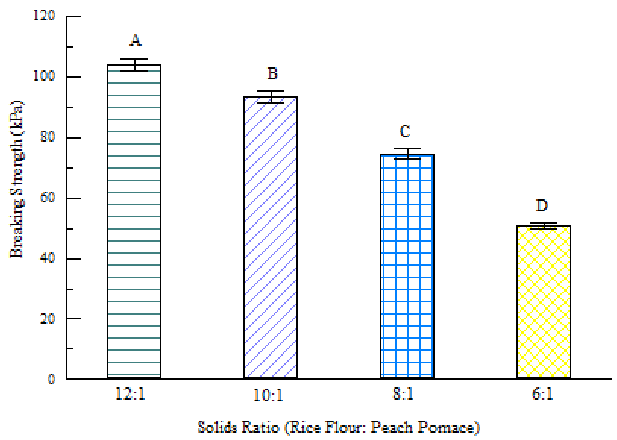

Figure 10 Effects of rice flour and peach pomace solids ratio on the breaking strength of the extrudates. Bars with different letters are significantly different from each other

CONCLUSION

The addition of peach pomace to rice flour had significant effects on the physical and textural properties of the extrudates. An increase in the peach pomace level in the feed mix significantly increased porosity, and radial and overall expansion ratios. The reverse trend was observed for apparent and true densities, and breaking strength of the extrudates, which systematically decreased with increasing level of peach pomace in the feed mix. Breaking strength of extrudates exhibited a strong negative linear correlation with radial expansion ratio. The results of this study indicate that fruit processing co-products can be utilized for production of extruded products without compromising physical and textural attributes. The addition of peach pomace to rice flour provides a tool to manufacture nutritious extruded products with high soluble fiber content and desirable textural attributes.

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