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DEVELOPMENT AND EVALUATION OF EXTRUDED PRODUCT OF RICE FLOUR AND APPLE POMACE

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ABSTRACT
The study was conducted in the Division of Food Science and Technology, SKUAST-K. Apple pomace was added in different proportions (0, 3, 6 and 9) to rice flour (Shalimar Rice 1) commonly grown in temperate region of Kashmir valley. The experiment was laid down in factorial completely randomized design (CRD), the formulation was extruded at different moisture content (14-16%), screw speed (500 rpm) and barrel temperature (140-160°C). The extruded product was analyzed for the various parameters. The results revealed that density, water absorption index, L* value and hardness increased with the increase in moisture and decreased with the increase in barrel temperature. While as volume expansion ratio, water solubility index, a* value and b* value decreased with the increase in moisture and increased with the increase in barrel temperature. Also density, WSI, a* value, b* value and hardness increased with the increase in pomace level. However, WAI, volume expression ratio and L* value decreased with the increase in pomace level. It was observed that the rice extrudates blended with 3 per cent apple pomace and with 14 per cent feed moisture extruded at 160°C barrel temperature were found to be superior in terms of physical properties studied in comparison to other treatment.

INTRODUCTION

Fruit and vegetable wastes are inexpensive, available in large quantities, characterized by a high dietary fibre content resulting with high water binding capacity and relatively low enzyme digestible organic matter (Serena and Knudsen, 2007). A number of researchers have used fruits and vegetable by-products such as apple, pear, orange, peach, blackcurrant, cherry, artichoke, asparagus, onion, carrot pomace (Grigelmo-Miguel and Martin-Belloso, 1999; Nawirska and Kwasnievska, 2005) as sources of dietary fibre supplements in refined food. Cereal grains are generally used as major raw material for development of extruded snack foods due to their good expansion characteristics because of high starch content. The broken rice is a by product of rice milling process. The rice portion can have varying percentages (5 - 7%) of broken kernels which contain nutritive value similar to whole rice and are available readily at relatively lower cost. Rice contains approximately 7.3% protein, 2.2% fat, 64.3% available carbohydrate, 0.8% fiber and 1.4% ash content (Zhoul *et al.*, 2002). Rice flour has become an attractive ingredient in the extrusion industry due to its bland taste, attractive white color, hypoallergenicity and ease of digestion (Kadan *et al.*, 2003).

Consumption of Fruit and vegetable juices as a source of have found to be suitable and alternative option to the traditional caffeine containing beverages such as coffee, tea, or carbonated soft drinks (Kaur *et al.*, 2009) **.** Because of overall increase in natural juice consumption and as such their waste like pomace readily available and utilizable. Apple pomace is a by-product obtained during apple juice processing. Besides, it also has good residual amount of all the vitamins, minerals and dietary fibre. So far the left over pomace from processing factories received after juice extraction of apple are not properly utilized. Moreover, pomace has become a source of environmental problem because of lacking of its proper disposal as a waste material; it needs to be utilized in a proper way. The pomace is quite perishable as it contains about 88 $\pm$ 2% of moisture. A promising way is to store the apple pomace in dried form and utilize in the development of bakery products specifically extrudates, which are now a day's becoming more popular than other bakery products in ready to eat food category. The incorporation of cauliflower trimmings into ready to- eat expanded products up to 10% level was suggested by Stojceska *et al.* (2008). Altan *et al.* (2008) processed the blends of barley flour and tomato pomace; barley flour and grape pomace and corn flour and tomato pomace in a co-rotating twin-screw extruder. Limited information is available on extrusion processing of apple by-products. In Jammu and Kashmir Rice is the staple diet for majority of population. The broken rice percentage is also considerably high in the state (35%) as most of the millers still rely on obsolete equipments to mill the paddy. Extrusion behaviour studies of different varieties of rice shall help in choosing the rice varieties for development of extruded products with better consumer acceptability. Further utilization of apple pomace in the development of extruded products, if found suitable can go a long way in the commercial production of highly nutritious and cheap extruded products. The study was to undertaken to study the effect of apple pomace incorporation in the rice based extruded products for the development of health food to optimize the rice flour and apple pomace blend extruded product.

MATERIALS AND METHODS

Raw material

In the experiment, rice variety viz Shalimar Rice 1 was taken for the study. The paddy was procured from Seed Processing Centre, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K) were milled to obtain rice in the modern rice mill in the Division of Post Harvest Technology, SKUAST-Kashmir. The milled rice was grounded in a mill (model 3303, perten sewden) to the finess that passes through 2mm sieve. The apple pomace to be incorporated was procured from the apple juice concentrate plant (Jammu & Kashmir Horticultural Produce Marketing & Processing Corporation) Doabgah, Sopore.

Experimental design

Apple pomace powder with the level of 0, 3, 6 and 9 per cent of rice flour and 10 per cent spice mix was added to the mixture. The blended materials were then metered into the extruder with a single screw volumetric feeder at two different feed moisture levels (14 and 16%) and barrel temperature (140 and 160^{o}C). Each treatment was replicated thrice in completely randomized design with 500 g of flour as a unit of replication.

Preparation of apple pomace powder for incorporation in rice extrudates

The apple pomace was dried in cabinet drier and the temperature of the dryer was set at 60°C, up to the moisture content of 5 ± 1 per cent (wet basis). The dried pomace was ground in food processor with grinder attachment to the finess that passes through the sieve of 2 mm size.

Extrusion process

The extrusion experiment was performed in a co-rotating intermeshing twin screw extruder (Clextral BC-21, Firminy, France). Temperature of first, second and third zone was maintained at 30, 60 and 90^{o}C respectively, throughout the experiment, while the temperature at the fourth zone was varied to the experimental design.

Specific mechanical energy (SME)

Specific mechanical energy (Wh/kg) was calculated from rated screw speed (682 rmp), motor power rating, actual screw speed, per cent motor torque and mass flow rate (kg/h) as per the following formula (Pansawat *et al.*, 2008)

$$SME = \frac{\text{Actual Screw Speed (rpm)}}{\text{Rated Screw Speed (rpm)}} \times \frac{\text{\% motor torque}}{100} \times \frac{\text{motor power rating}}{\text{mass flow rate}} \times 100$$

Water absorption index (WAI) and water solubility index (WSI) of extrudates

WAI and WSI were determined according to the method developed for cereals (Anderson et al., 1969; Yagci and Gogus, 2008; Stojceska et al., 2008). The ground extrudates were suspended in water at room temperature for 30 min, gently stirred during this period, and then centrifuged at 3000 g for 15 min. The supernatants were decanted into an evaporating dish of known weight. The WAI was the weight of gel obtained after removal of the supernatant per unit weight of original dry solids. The WSI was the weight of dry solids in the supernatant expressed as a percentage of the original weight of sample.

$$WAI\,(g/g) = \frac{\text{weight sediment}}{\text{weight of dry solid}}$$

$$WSI\,(\%) = \frac{\text{weight of dissolved solids in supernatant}}{\text{weight of dry solids}} \times 1000$$

Bulk density (g/ml)

The bulk densities of extrudates were determined by volumetric displacement procedures as described by Patil *et al.* (2007). The volume of expanded sample was measured by using a 100-ml graduated cylinder by rapeseed displacement. The volume of 20 g randomized was measured for each test. The ratio of sample weight and the replaced volume in the cylinder was calculated as bulk density (w/v).

Expansion ratio

Expansion ratio was determined (Halek and Chang, 1992) by applying a Digital vernier calliper to measure the average thickness of extrudate, 10 randomly chosen pieces of extrudate from each test run of each replicate and calculated as the ratio between the thickness of the extrudate and the die diameter. Volume Expansion Ratio is given as average value of six calculations.

ER = D/d,

Where, D = diameter of the extrudate, and d = diameter of the die hole. The 10 randomly extrudate diameter was measured and their average was taken as final reading.

Colour

Colour was determined by using Hunter Lab Colorimeter (Model SN3001476, Accuracy Micro sensors, New York).

Hardness (g)

The hardness of the extrudates was carried out by using texture analyzer.

RESULTS AND DISCUSSION

Specific mechanical energy (Wh/kg)

The data with regard to effect of barrel temperature, feed moisture and apple pomace on SME of extruded product is presented in Table-1. The data indicated that SME decreased with the increase in feed moisture and barrel temperature. However, increasing apple pomace level in the blends increased the SME inputs in extrusion cooking significantly. The SME was recorded less in 0 per cent apple pomace rice extruded and higher at 9 per cent apple pomace rice extrudate. The observed effect of apple pomace on the SME was similar as Hsieh *et al.* (1991) in extrusion of sugar beet fibre and corn meal, they reported that less water was available for starches in the corn meal in the presence of sugar beet fibre, because the viscosity of the starch-water system increases with decreasing water content, torque and specific energy increased with the increased sugar beet fibre. This effect could be explained as, by adding apple pomace to rice flour gives a more viscous melt requiring a higher torque and cause an increase in SME inputs. SME decreased with increased in barrel temperature and increased with increased in feed moisture (Dogan and Karwe, 2003). Increase in Barrel temperature suggests reduced in viscosity which ultimately leads to

Table 1: Effect of apple pomace on specific mechanical energy (Wh/kg) of rice flour apple pomace blend extrudate

Pomace level(%)	Moisture (%)					
	14			16		
	(T1)	(T2)	Mean	(T1)	(T2)	Mean
0	106	110	108	93	87	90
3	120	111	115	107	91	99
6	122	113	117	109	93	101
9	125	115	120	117	95	106
Mean	118	112	115	106.5	91	99

C.D pd″0.05 Pomace (P) = 0.67; Moisture (M) = 0.47; Barrel Temperature (T) = 0.47; P x M = 0.94; P x T = 0.94; M x T = 0.67; P x M x T = 1.34 (T1 = 140^0C T2 = 160^0C)

Table 2: Effect of apple pomace on bulk density (g/ml) of rice flour apple pomace extrudate

Apple pomace(%)	Moisture (%)					
	14			16		
	(T1)	(T2)	Mean	(T1)	(T2)	Mean
0	0.16	0.16	0.16	0.26	0.22	0.24
3	0.18	0.16	0.17	0.34	0.33	0.33
6	0.18	0.17	0.17	0.39	0.36	0.37
9	0.19	0.19	0.19	0.37	0.37	0.37
Mean	0.17	0.17	0.17	0.34	0.32	0.32

C.D pd″0.05 Pomace (P) = NS; Moisture (M) = NS; Barrel Temperature (T) = NS; P x M = NS; P x T = NS; M x T = NS; P x M x T = NS (T1 = 140^0C T2 = 160^0C)

Table 3: Effect of apple pomace on water solubility index (%) of rice flour apple pomace extrudate

Pomace level(%)	Moisture (%)					
	14			16		
	(T1)	(T2)	Mean	(T1)	(T2)	Mean
0	12.73	12.95	12.84	11.49	11.79	11.64
3	13.39	13.56	13.47	12.31	12.57	12.44
6	13.63	13.84	13.73	12.21	12.89	12.55
9	14.11	14.23	14.17	13.68	13.97	13.82
Mean	13.46	13.64	13.55	12.42	12.80	12.61

C.D pd″0.05 Pomace (P) = 0.04; Moisture (M) = 0.03; Barrel Temperature (T) = 0.03; P x M = 0.06; P x T = 0.06; M x T = 0.04; P x M x T = NS (T1 = 140^0C T2 = 160^0C)

Table 4: Effect of apple pomace on water adsorption index (g/g) of rice flour apple pomace extrudate

Pomace level(%)	Moisture (%)					
	14			16		
	(T1)	(T2)	Mean	(T1)	(T2)	Mean
0	7.53	7.01	7.27	8.74	8.68	8.71
3	7.34	6.87	7.10	8.58	7.66	8.12
6	7.11	6.49	6.80	8.24	8.12	8.18
9	6.93	6.13	6.53	7.95	7.86	7.90
Mean	7.23	6.62	6.92	8.38	8.08	8.23

C.D pd″0.05 Pomace (P) = 0.14; Moisture (M) = 0.1; Barrel Temperature (T) = 0.1 P x M = NS; P x T = NS; M x T = 0.14; P x M x T = NS (T1 = 140^0C T2 = 160^0C)

Table 5: Effect of apple pomace on volume expansion ratio of rice flour apple pomace extrudate

Pomace level(%)	Moisture (%)					
	14			16		
	(T1)	(T2)	Mean	(T1)	(T2)	Mean
0	3.37	3.71	3.54	2.88	3.16	3.02
3	3.29	2.96	3.12	2.51	2.27	2.39
6	3.21	3.11	3.16	2.92	2.14	2.53
9	3.13	2.88	3.00	2.22	2.10	2.16
Mean	3.25	3.16	3.20	2.63	2.42	2.52

C.D pd—0.05 Pomace (P) = 0.04; Moisture (M) = 0.03; Barrel Temperature (T) = 0.03; P x M = 0.06; P x T = 0.06; M x T = 0.04; P x M x T = 0.09(T1 = 140^0C T2 = 160^0C)

reduced SME (Chang and Wang., 1999). The effect of apple pomace on bulk density of rice flour extrudate has been presented in Table 2. It was evident from the table that extrudate density was influenced by feed moisture, barrel temperature and apple pomace. Perusal of the data revealed an increasing trend in density with increase in feed moisture and apple

Table 6: Effect of apple pomace on colour (L*) of rice flour apple pomace blend extrudate

Pomace level(%)	Moisture (%)					
	14			16		
	(T1)	(T2)	Mean	(T1)	(T2)	Mean
0	55.22	53.80	54.51	57.42	55.52	56.47
3	46.63	45.22	45.92	48.58	46.34	47.46
6	45.34	42.61	43.97	46.77	44.41	45.59
9	42.10	38.89	40.29	43.39	39.48	41.43
Mean	47.32	45.13	46.22	49.04	46.43	47.73

C.D pd"0.05 Pomace (P) = 0.52; Moisture (M) = 0.37; Barrel Temperature (T) = 0.37; P x M = 0.73; P x T = NS; M x T = NS; P x M x T = NS (T1 = 140^{0}C T2 = 160^{0}C)

Table 7: Effect of apple pomace on colour (a*) of rice flour apple pomace blend extrudate

Pomace level (%)	Moisture (%)					
	14			16		
	(T1)	(T2)	Mean	(T1)	(T2)	Mean
0	0.62	0.73	0.67	0.35	0.57	0.46
3	1.75	1.89	1.82	1.61	1.78	1.69
6	2.06	2.12	2.09	2.01	2.19	2.10
9	3.07	3.23	3.15	2.97	3.11	3.04
Mean	1.87	1.99	1.93	2.29	2.46	2.37

C.D pd"0.05 Pomace (P) = 0.02; Moisture (M) = 0.01; Barrel Temperature (T) = 0.01P x M = 0.02; P x T = 0.02; M x T = 0.02; P x M x T= 0.03(T1 = 140^{0}C T2 = 160^{0}C)

Table 8: Effect of apple pomace on colour (b*) of rice flour apple pomace blend extrudate

Pomace level(%)	Moisture (%)					
	14			16		
	(T1)	(T2)	Mean	(T1)	(T2)	Mean
0	17.33	19.91	18.62	14.44	17.24	15.84
3	20.69	21.65	21.17	22.84	23.72	23.28
6	22.93	23.48	23.20	23.75	23.92	23.83
9	24.04	24.48	24.26	24.65	25.35	25.00
Mean	21.25	22.38	21.81	21.42	22.56	21.97

C.D pd"0.05 Pomace (P) = 0.038; Moisture (M) = 0.027; Barrel Temperature (T) = 0.027 ; P x M = 0.54; P x T = 0.04; M x T = NS; P x M x T = 0.077 (T1 = 140^{0}C T2 = 160^{0}C)

pomace and decreasing trend with the increase in barrel temperature. The bulk density of rice flour apple pomace extrudate had a non significant effect of process variables. The bulk density was lowest at higher barrel temperature employed in samples with no addition of pomace, where as highest value was obtained at lower temperature in the samples with high apple pomace level. Feed moisture has been found to be the dominant factor effecting extrudate density and expansion (Faubion and Hoseney, 1982; Launay and Lisch, 1983; Fletcher *et al*., 1985; Ilo and Berghofer., 1999) which is agreement with our findings. The high dependence of the bulk density and expansion on the feed moisture would reflect its influence on elasticity characteristics of starch based material. Increased feed moisture content during extrusion would change the amylopectin molecular structure of material, reducing the melt elasticity thus decreasing the expansion and increasing the density of extrudates. Whereas, a decrease in the extrudate viscosity with increase in barrel temperature has also been reported in earlier findings (Mercier and Feillet (1975). The reduced viscosity effect would favour the bubble growth during extrusion. Moreover, the degree of superheating of water in the extrudate would increase at higher temperature, which leads to greater expansion (Fletcher *et al*., 1985; Ilo and Berghofer., 1999). The high apple pomace level means, higher retention of moisture which results in less expansion and higher density, which are in conformity with earlier finds of Dongan and Karwe, 2003; Hagnimana *et al*., 2006. The effect

Figure 1:

of apple pomace on water solubility index of rice flour apple pomace extrudate has been presented in Table 3. It was evident from the table water solubility index decreased with increase in feed moisture and increased with increase in barrel temperature and apple pomace. Water Solubility Index, often used as an indicator of degradation of molecular components (Kirby *et al*., 1988), measure the degree of starch conversion during extrusion, which is the amount of soluble polysaccharides released from the starch component after

Table 9: Effect of apple pomace on hardness (g) of rice flour apple pomace blend extrudate

Pomace level(%)	Moisture (%)					
	14			16		
	(T1)	(T2)	Mean	(T1)	(T2)	Mean
0	16.26	13.74	15.00	33.25	31.09	32.17
3	26.86	19.31	23.08	72.34	66.52	69.43
6	32.28	24.62	28.45	88.33	72.31	80.32
9	34.65	26.44	30.54	95.42	85.42	90.42
Mean	27.51	21.03	24.27	72.33	63.83	68.08

C.D pd—0.05 Pomace (P) = 0.1; Moisture (M) = 0.1; Barrel Temperature (T) = 0.1; P x M = 0.20;P x T = 0.20; M x T = 0.15; P x M x T =0.(T1 = 140^{0}C T2 = 160^{0}C)

extrusion (Ding *et al.*, 2005). The change in water solubility index may be due to extrusion conditions. Water solubility index is reported to be related to the presence of soluble molecules that have sometimes been attributed to dextrinization (Collona *et al.*, 1989). Mean value for water solubility index depicted a significant effect of apple pomace water solubility index with 9 percent level having highest water solubility index. While as water solubility index was found to be lowest in extrudate having 0% apple pomace level. Water solubility index exhibited an increasing trend with increase in pomace level when compared to extrudate without any added pomace. The increase in water solubility index with increase in apple pomace may be due to increase in fibrous pomace content in feed formation resulting in high free sugar. Similar trend was also reported by Navneet *et al.* (2010) and Kumar *et al.* (2010). Effect of apple pomace on water absorption index on rice flour apple pomace has been presented in Table-4.Water absorption index decreased with the increased in barrel temperature but increased with the increase in feed moisture The water absorption index measures the volume occupied by granule or starch polymer after swelling in the excess water, which maintains the integrity of the starch in aqueous dispersion (Manson and Hoseney, 1986). Gelatinization, the conversion of raw starch to a cooked and digestible material by the application of water and heat, is one of the important effects that extrusion has on the starch component of foods. The maximum gelatinization occurs at high moisture and low temperature or vice-versa (Lawton and Henderson, 1972). Also, WAI decreased significantly as the concentration of apple pomace increased. This may be attributed to relative decrease in starch content with addition of pomace and competition of absorption of water between pomace and available starch. The results are in agreement with those of Artz *et al.* (1990). They reported a decrease in water holding capacity when the ratio of fibre/corn starch increased in extrusion of corn fibre and corn starch blend. The similar results were also reported by Singh *et al.* (2007) and Altan *et al.* (2008). The effect of apple pomace on volume expansion ratio has been presented in Table 5. The analysis of date revealed that volume expansion ratio increased with the increase in barrel temperature and decrease with the increase in feed moisture. The expansion ratio of extrudate describes the degree of puffing undergone by the material as it exits the extruder. With the increase in apple pomace levels, a decreasing trend of expansion ratio was observed. The extrudate without apple pomace was observed to have higher volume expansion ratio. The extrudate with 9 per cent apple pomace level had the lowest volume expansion ratio in both the varieties. When extrusion melts exits the die, there is a sudden shift from high pressure to atmospheric pressure. This pressure drops causes a flash-off of internal moisture and water vapour pressure which is nucleated to form bubbles in the molten extrudate, allow the expansion of the melt (Arhaliars *et al.*, 2003). Increasing level of pomace resulted in decrease in volume. This may be attributed to dilution effect of pomace on starch. Similar trend was observed by Sokhey *et al.* (1997). Colour is an important quality factor directly related to the acceptability of food products, and is an important physical property to report for extrudate products .The L* value showed a decreasing trend with the increase in barrel temperature and an increasing trend with increase in feed moisture (Table 6). Whereas, an increasing trend was recorded in redness (a*-value) and yellowness (b*-value) with the increase in barrel temperature; and a decreasing trend with the increase in feed moisture (Table 7and 8).

Overall it was observed that colour was mostly influenced by barrel temperature and to some extent by the feed moisture. The higher the feed moisture content, the brighter was the colour of rice extrudate, which was characterized by high L* value and low a* value. High temperature in combination with low water content favours the millards reaction between reducing sugar and free amino acid groups resulting in higher yellowness (Anastase *et al.*, 2006). The similar trend in L* and a* value was recorded by Anastase *et al.* (2006). Further, apple pomace was an important variable in defining the colour of extrudate. The L*, a* and b* values showed marketed change due to addition of apple pomace only. An increase in apple pomace level decreased the L* value of samples and increased a* value. This can be attributed to the presence of various pigments in the apple pomace. Similar result was found by Ilo and Berghofer (1999). They also reported that the changes in yellowness during extrusion of extrudates induced by the effect of two different reactions: the non enzymatic browning and pigment destruction. They also concluded that some of the caroteniods might have been damaged by the thermal treatment and some browning might have made up the colour loss. Thus increasing apple pomace content resulted in a significant increase in the extrudate b* value. The effect of barrel temperature, feed moisture and apple pomace on the texture or hardness of the rice extrudate is presented in Table 9. The data in the table reflects the hardness of extrudate or the forces (N) needed to break the product. The textural properties of extrudates are determined by measuring the force required to break the extrudate. The higher value of maximum peak force required, which means the force indicates the hardness of the sample (Li *et al.*, 2005). The data further revealed that the force required increased with the increase in feed moisture and apple pomace but decreased with increase in barrel temperature. The mean force required to break the extrudate was found maximum in 9 per cent apple pomace level. Whereas minimum force required was observed in extrudate without apple pomace. The increase in hardness with the increase in moisture was possibly due to availability of ample water for the formation of harder structure which leads to less expansion of extrudates. At the same time, the decrease in hardness with the increase in barrel temperature was possibly due to the less residual moisture available during extrusion process (Kumar *et al.*, 2010). The decreasing hardness with increase in barrel temperature and increase with increase in feed moisture was also reported by Altan *et al.* (2008). The increase in apple pomace results in increase in density, with high density product being naturally harder. Similar result was observed by Ding *et al.* (2006).

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