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Development of mango extrudates by extrusion processing

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Fruits and vegetables are an important nutritional requirement for human beings as these foods not only meet the quantitative needs to some extent but also supply vitamins and minerals, which improve quantity of our diet and maintain health. It is, therefore, necessary to make them available for consumption throughout the year in processed form. Drying is the oldest method for preserving food as it controls microbial growth, reduces size of food, thus, providing it good storage and packaging properties. Fruits and vegetables selected for drying should be of the best quality- fresh and ripe. To dry them successfully these should have good rheological and textural properties. The good quality fresh mangoes were procured from the market, washed, peeled and processed to get the pulp. The mango kurkure made from roasted wheat and barley was uniform in texture, lacked crispiness and gave good flavour.

Key Words : Mango extrudate, Flavour, Texture, Extruder, Mango pulp

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INTRODUCTION

Mango (*Magnifera indica* L.) is one of the most important tropical and subtropical fruit of the world and is popular both in fresh and processed form. It is commercially grown in more than 80 countries (Vijayanand *et al.*, 2015). India is the largest producer of mango, with an area of 2.312 million ha with an annual production of 15.026 million tonnes, which accounted for 40.48 per cent of the total world production (FAO, 2009). The other leading mango producing countries of the world are Brazil, China, Mexico, Pakistan, Bangladesh, Indonesia, Thailand, Nigeria, Philippines and Haiti (APEDA, 2010). The fruit has attractive colour, excellent flavor and delicious taste with high nutritional value. Due to higher moisture content (85%) it has very poor keeping quality and cannot withstand any adverse climatic conditions during storage (Akhtar *et al.*, 2010). This results in loss of 30 per cent of fruits every year (Thind *et al.*, 2002). To overcome the post harvest losses and to increase its shelf-life, the surplus mango has to be processed into shelf stable products like sterilized pulp or dried flakes and powders for consumption (Saxena and Arora, 1997 and Srinivasan *et al.*, 2000). Ripe mangoes are processed as canned and frozen slices, juices, nectar, puree and various dried products. The cost of processed mango products is also expensive for the general population in the areas where most mangoes are grown (FAO, 1995).

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Fruit based extruded products:

Although extrusion technology has been used extensively to create carbohydrate based snack foods, the use of extrusion to create fruit based snacks is a relatively new area of research. The benefits that could be seen from creating a food product using this method included the health appeal of a fruit based snacks, the convenience of ready to eat product and the ease of production which extrusion provides.

Novel expanded snacks were formed in the late 1980's by co-extrusion of rice flour with dried fruits and fruit juice concentrates. Extruded snacks exhibited comparable yield and sensory properties compared to extrudate made exclusively from rice. The juices performed better than the dried fruit in regards to expansion. Citric acid addition did not significantly improve extrudate properties with the exception of improved colour retention.

Akdogan and Mchugh (1999) developed a semi-empirical nonlinear model to incorporate the effects of extruder operating conditions (temperature, moisture and shear rate) on viscosity of peach puree in a lab-size twin screw extruder. Experimental apparent viscosity varied from 40 to 130 Pa.s, depending on the operating conditions. Colour indicatives (L, a, b) and extrudate density were mainly influenced by the moisture content. Water activity was only influenced by moisture.

Alam *et al.* (2015) investigated the effects of extrusion process parameters, *i.e.*, screw speed (300–500 rpm), die temperature (120–180°C), feed moisture content (14-20%) and sample formulation (60–80% rice flour/10–30% pulse flour and 10% carrot pomace), on the functional (bulk density, expansion ratio, water absorption index and water solubility index), physical (hardness and overall acceptability) and system (specific mechanical energy) properties of an expanded rice-based snack product. The experiments were planned using a Box-Behnken design and the extrusion process parameters were optimized for maximum ER, WAI and OA and minimum BD, WSI, SME and hardness within the experimental range using response surface methodology. Among the process parameters studied, sample formulation demonstrated a significantly lower effect on the response variables studied. The optimal extrusion process parameters obtained were an 80:10:10 (rice flour/pulse flour/ carrot pomace powder) sample formulation, 14 per cent feed moisture content, 323 rpm screw speed and 120°C die temperature.

Altan *et al*. (2008) evaluated the effects of independent variables, namely die temperature (140–160 °C), screw speed (150–200 rpm) and pomace level (2–10%, db) on product responses (expansion, bulk density, texture and colour) using Central Composite design of response surface Methodology. The barley flour–grape pomace blends were extruded in a 30 mm APV co-rotating twin-screw extruder. Sensory analysis was carried out for selected extrudates for appearance (colour, porosity), taste (bran flavour, bitterness and sweetness), off-odor, texture (hardness, crispness and brittleness) and overall acceptability. Multiple regression equations were obtained to describe the effects of each variable on product responses. Blends of 2 per cent grape pomace extruded at 160°C, 200 rpm and 10 per cent grape pomace extruded at 160°C, 150 rpm had higher preference levels for parameters of appearance, taste, texture and overall acceptability. However, graphical optimization studies resulted in 155–160°C, 4.47–6.57 per cent pomace level and 150–187 rpm screw speed as optimum variables to produce acceptable extrudates.

Bhople *et al.* (2017) prepared the snacks by using a Brabender single screw laboratory extruder by extrusion cooking of rice (*Oryza sativa* L.), ashwagandha (*Withania somnifera*) and spinach (*Spinacia oleracea*) flour blends. It was observed that 18 per cent moisture content of feed, 80:15:5 (rice flour: ashwagandha: spinach powder) of blend ratio, 180°C barrel temperature and 100 rpm of screw speed gave the highest mass flow rate and sectional expansion index of extrudate, while 15 per cent moisture content, 80:15:5 of blend ratio of feed, 140° C of barrel temperature and 80 rpm of screw speed gave lowest bulk density of extrudate.

Camacho-Hernandez *et al.* (2014) evaluated the effect of barrel temperature (BT, 98.8–141.2°C) and feed moisture (FM, 19.93–34.07%) as independent factors on physico-chemical characteristics of microwave-expanded extruded third-generation (3G) snacks obtained from blue corn and corn starch. Single-screw laboratory extruder and a central, composite, rotatable experimental design were used. The optimum area of the extrusion process ranged from 120°C to 126°C for BT and from 23.8 per cent to 25.2 per cent for FM. In optimal conditions, the product showed an expansion index of 4.8, a penetration force of 12.42 N, a specific mechanical energy of 169.08 kJ/kg and 71.09 mg of total anthocyanin content/kg.

Khanal *et al.* (2009) identified optimal extrusion variables to enhance the contents of monomers and dimers at the expense of large molecular weight procyanidin oligomers and polymers. Extrusion variables temperature (160 and 180^0 C) and screw speed (150 and 200 rpm) were tested using mixtures of blueberry pomace with decorticated white sorghum flour at a ratio of 30:70 and 45 per cent moisture content. Extrudates were analyzed for procyanidin composition and total anthocyanin content. Extrusion processing reduced total anthocyanin contents by 33 per cent to 42 per cent indicating that additional treatments are needed to retain the pigments. These results demonstrate that extrusion processing can be used to increase procyanidin monomer and dimers in blueberry pomace.

Lohani and Muthukumarappan (2017) investigated the effect of extrusion processing on total phenolic content (TPC), antioxidant activity (AA) along with some selected textural and functional properties of the corn flour, hydrodynamic cavitated sorghum flour and apple pomace blended extrudate. Box behnken design was applied for three levels of apple pomace ratio APR (10, 20 and 30%), feed moisture FM (25, 30 and 35% wb), extrusion die temperature *T* (80, 110 and 140°C) and screw speed SS (100, 150 and 200 rpm) as extrusion parameters. Extrusion cooking at higher APR and low *T* and SS increased the TPC and AA. Expansion ratio, brittleness, crispness and water solubility index of extrudates were increased while hardness and water absorption index decreased compared to that of control extrudates. At optimum conditions of 30 per cent APR, 25 per cent wb FM, 132°C *T* and 108 rpm SS, TPC and AA of extruded products were 120.1 mg GAE/100 g DW and 308.7 µmol TE/100 g DW, respectively, whereas those found in control blend were 123.2 mg GAE/100 g DW and 258.9 µmol TE/100 g DW, respectively.

McHugh and Huxsoll (1999) 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 colour, water activity and texture were determined. 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 colour; however, sugar addition did significantly increase the L, a and b values of peach/ starch gels.

Ruiz-Armenta *et al.* (2017) studied the effect of extrusion temperature (ET; 89.8–140.2°C), moisture content (MC; 21.10–32.89%) and dehydrated naranjita bagasse (DNB) content (1.12–11.88%) on TGS properties, such as, carotenoids content, physical and sensory characteristics. For data analysis, response surface methodology was used. The highest expansion index and the lowest penetration force were presented at high ET and low MC, whereas the highest carotenoids content and ΔE were presented at high DNB. Also, the highest sensory acceptability was presented combining high ET and MC and low DNB. The optimal processing conditions were ET = 125°C, MC = 23 per cent and DNB = 8.03 per cent. TGS with acceptable physical and sensory properties, in addition to important carotenoid levels, were obtained.

Selani *et al.* (2014) characterised pineapple pomace (PP) and evaluated its application in extrusion to enhance fibre content of the final product. The pomace had low fat (0.61%) and high dietary fibre (45.22%), showing its potential for fibre enrichment of nutritionally poor products, as some extruded snacks. Results also showed low microbiological counts, water activity and pH indicating good microbiological quality and low risk of physico-chemical deterioration. During extrusion, pomace (0%, 10.5% and 21%), moisture (14%, 15% and 16%) and temperature (140 and 160°C) were evaluated. The PP addition decreased expansion and luminosity; while increasing redness of the extrudates compared to the control (0% pomace/14% moisture/140°C). When hardness, yellowness, water absorption and bulk density were compared to the control, there was no effect ($p > 0.05$) of 10.5 per cent PP addition on the extrudates, indicating that, at this level, PP could be added without affecting the properties of the final extruded product.

Singha and Muthukumarappan (2018) investigated the single screw extrusion of apple pomace–defatted soy flour–corn grits blends and the product properties using response surface methodology. Five different blends at a level of 0–20 per cent w/w apple pomace were extrusion cooked with varied barrel and die temperature (100–140°C), screw speed (100–200 rpm) and feed moisture content (14–20% wet basis). Increasing apple pomace content in the blends significantly ($P<0.05$) increased the bulk density, the total phenolic content and the antioxidant activity of the extrudates. Optimal extrusion cooking conditions most likely to produce apple pomace-enriched extruded snack products were at 140°C barrel and die temperature, 20 per cent feed moisture content and 200 rpm screw speed.

Tovar-Jimenez *et al.* (2015) estimated the expansion index, bulk density, penetration force, carotenoid content, and dietary fibre for third-generation snack which was a mixture of orange vesicle flour, commercial nixtamalized corn flour and potato starch which were extruded using a Brabender Laboratory single screw extruder (2:1 L/D). Response surface methodology was applied using a central composite rotatable experimental design to evaluate the effect of moisture content and extrusion temperature. Temperature mainly affected the expansion index, bulk density and penetration force, while carotenoids content was affected by moisture content.

White *et al.* (2010) determined the changes in the anthocyanin, flavonol and procyanidin contents due to extrusion by HPLC of cranberry pomace mixed with corn starch in various ratios (30:70, 40:60, 50:50 pomace/corn starch DW) and extruded using a twin-screw extruder at three temperatures (150, 170, 190° C) and two screw speeds (150, 200 rpm). Antioxidant capacity of the extrudates was determined using oxygen radical absorbance capacity (ORAC). Anthocyanin retention was dependent upon barrel temperature and per cent pomace. The highest retention was observed at 150° C and 30 per cent pomace. ORAC values increased upon extrusion at 170 and 190° C.

Hence, there is a great scope of processing mango into value added products using extrusion technology. An attempt was made to develop novel value added product using mango pulp.

METHODOLOGY

Extrusion machine or extruder:

A low cost collet extruder (Fig. A) working at feed rate of 25 kg/hr and 10 H.P. motor along with an input of 240 volts giving an output of 50 volts, 1.5 amperes and also with an output of 110 volts for running the extruder shaft. It produces ready to eat snacks from cereals, millets and other ingredients and has been procured at CIPHET, Ludhiana to conduct experiments on developing the ready to eat value added products from various ingredients like rice broken, millets, coarse grains and fruit pulps similar to the ones developed by long barrel single screw and twin screw extruders and compare their physical, textural and sensory qualities *vis-a –vis* their cost of production. The attempts are being made for optimization of process parameters for gluten free health foods from millets and legumes.

Fig. A : Low cost collet extruder

The experimental fruit mango 2.125 kgs was procured from the local market of Ludhiana. The fruit was cleaned and washed manually. Washing was required for removing dust and extraneous matter present on the fruits. Fruits were washed first with detergents like Teepol (0.1%) followed by fresh water. Then peeling of fruits was done with stainless steel knives and the mango pulp was made with the help of mixer/grinder and seed and peeled material was thrown away. A finely ground porridge (roasted wheat) was taken and mixed with extracted mango pulp in the ratio of 82:18. The mixture was extruded through the collet extruder machine to get the extrudate. The extrudate was analyzed in its texture and flavour. The tests were also performed using the sample with (roasted barley) in the ratio of 80:20 and again the extrudate was analyzed for its texture and flavour.

Statistical analysis :

It was done by applying the Spearman's rank correlation co-efficient test for determining the 'r' correlation co-efficient between weight of peeled and pulped mangoes. The mean, S.D. and co-efficient of variation of weight of peeled mango and pulped mangoes and regression equation between total weight of the mixture and weight of the product after extrusion was calculated using MS-Excel 2007.

OBSERVATIONS AND ASSESSMENT

The weight of peeled mango and pulped mango was taken and both is represented in Table 1.

Regression equation :

$$y = 752 + 0.4x \text{ with } R^2 = 1$$

Fig. 1 : Extrudates of mango pulp with roasted wheat grit

Fig. 2 : Extrudates of mango pulp with roasted barley grit

Table 1 : Weight of peeled and pulped mangoes

Wt. of peeled mangoes in (g)	Wt. of pulped mangoes in (g)
604	767.3
560.2	733.1
536.3	710.7
504.5	676.6
229.7	219.7
225	203.5
220.7	193.7
215.8	181.5
213.4	176
212	173.3
190	145
190	140

Table 2 : Mango extrudate made from roasted wheat

Mango pulp (g)	Roasted wheat (g)	Mixture (Ratio)	Weight of product after extrusion (g)
165	727.8	18:82	356.8

Table 3 : Mango extrudate made from roasted barley

Mango pulp (g)	Roasted barley (g)	Mixture (Ratio)	Weight of product after extrusion (g)
200	800	20:80	628.3

where,

y = Total weight of the mixture

x = Weight of the product after extrusion.

The Spearman's rank correlation co-efficient between weight of peeled and pulped mangoes was 0.99. The mean of weight of peeled and pulped mangoes was 325 g and 360 g, respectively, standard deviation of weight of peeled and pulped mangoes was 168 and 268, respectively and co-efficient of variation of weight of peeled and pulped mangoes was 52 per cent and 75 per cent, respectively.

Conclusion :

There is 60 per cent and 37 per cent loss during extrusion in mango extrudate made from wheat and barley, respectively. The mango kurkure made from roasted wheat and barley was uniform in texture, lacked crispiness and gave good flavour. There was difference in colour for mango extrudates made from roasted wheat and barley, respectively.

LITERATURE CITED

Akdogan, H. and Mchugh, T.H. (1999). Twin screw extrusion of peach puree: Rheological properties and product characteristics. *J. Food Proc. Preserv.,* **23**(4): 285-305.

Akhtar, S., Naz, S., Mahmood, S., Nasir, M. and Ahmad, A. (2010). Physico-chemical attributes and heavy metal content of mangoes (*Mangifera indica* L.) cultivated in different regions of Pakistan. *Pakistan J. Bot.,* **42**(4): 2691-2702.

Alam, M.S., Kumar, S. and Khaira, H. (2015). Effects of extrusion process parameters on a cereal-based ready-to-eat expanded product formulated with carrot pomace. *Cereal Foods World* , **60** (6) : 287-295.

Altan, A., McCarthy, K.L. and Maskan, M. (2008). Twin-screw extrusion of barley–grape pomace blends: Extrudate characteristics and determination of optimum processing conditions. *J. Food Engg.,* **89**(1):24-32.

Bhople, S., Singh, M. and Thakur, S.(2017). Effect of process and machine parameters on physical properties of extrudate during extrusion cooking of rice, ashwagandha powder and spinach powder blends. *Internat. J. Chem. Stud.,* **5** (6) : 1657-1662.

Camacho-Hernandez, I.L., Zazueta-Morales, J.J., Gallegos-Infante, J.A., Aguilar-Palazuelos, E. , Rocha-Guzmán, N.E., Navarro-Cortez, R.O., Jacobo-Valenzuela, N. and Gómez-Aldapa, C.A. (2014). Effect of extrusion conditions on physico-chemical characteristics and anthocyanin content of blue corn third-generation snacks. *CyTA - J. Food,* **12** (4): 320-330. DOI: 10.1080/19476337.2013.861517.

Khanal, R.C., Howard, L.R., Brownmiller, C.R. and Prior, R.L. (2009). Influence of extrusion processing on procyanidin composition and total anthocyanin contents of blueberry pomace. *J. Food Sci.,* **74**(2):52-58.

Lohani, U.C. and Muthukumarappan, K. (2017). Effect of extrusion processing parameters on antioxidant, textural and functional properties of hydrodynamic cavitated corn flour, sorghum flour and apple pomace based extrudates. *J. Food Proc. Engg.,* **40** (3) e12424.

Mchugh, T.H. and Huxsoll, C.C. (1999). Extrusion processing of restructured peach and peach/starch gels. *LWT- Food Sci. & Tech.,* **32**(8) : 513-520.

Ruiz-Armenta, X.A., Zazueta-Morales, Jose de Jesus, Aguilar-Palazuelosa, E., Delgado-Nieblasa, C.I., López-Diaza, A., Camacho-Hernández, I.L., Gutiérrez- Dorado, R. and Martínez-Bustos, F. (2017). Effect of extrusion on the carotenoid content, physical and sensory properties of snacks added with bagasse of naranjita fruit: optimization process. *Cyta – J. Food,* **16**(1): 172–180.

Saxena, R. and Arora, V.P.S. (1997). Consumers of processed fruit and vegetables products. An analysis of buying behaviour. *Indian Food Industry,* **16**(3): 25-36.

Selani, M.M., Brazaca, S.G.C., dos Santos Dias, C.T., Ratnayake, W.S., Flores, R.A. and Bianchini, A. (2014). Characterisation and potential application of pineapple pomace in an extruded product for fibre enhancement. *Food Chem.,* **163** : 23-30.

Singha, P. and Muthukumarappan, K. (2018). Single screw extrusion of apple pomace-enriched blends: Extrudate characteristics and determination of optimum processing conditions. *Food Sci. & Tech. Intl.,* **24**(5) : 447-462.

Srinivasan, N., Elangovan, S. and Chinnaiyan P. (2000). Consumer perception towards processed fruit and vegetables products. *Indian Econ. Panorama,***10**(3):11-12.

Thind, K.K., Grewal, K.S. and Bakshi, A.K.(2002). Method of preparation and keeping quality of reconstituted skim milk based mango beverage. *Beverage & Food World*, **29**(8): 60-62.

Tovar-Jimenez, X., Caro-corrales, J., Gomez-Aldapa, C.A., Zazueta-Morales, J., Limon-Valenzuela, V., Castro-Rosas, J., Hernandez-Avila, J. and Aguilar-Palazuelos, E. (2015). Third generation snacks manufactured from orange by-products: physico-chemical and nutritional characterization. *J. Food Sci. &Tech.,* **52**(10):6607-6614.

Vijayanand, P., Deepu, E. and Kulkarni, S.G. (2015). Physico-chemical characterization and the effect of processing on the quality characteristics of Sindura, Mallika and Totapuri mango cultivars. *J. Food Sci. & Tech.,* **52**(2):1047-1053.

White, B.L., Howard, L.R. and Prior, R.L.(2010). Polyphenolic composition and antioxidant capacity of extruded cranberry pomace. *J. Agric. Food. Chem.,* **58**(7): 4037-4042.

■ WEBLIOGRAPHY

APEDA (2010) Available from *http://www.apeda.in/agriexchange/Market%20Profile/one/MANGO.aspx.*

Food and Agriculture Organization (1995). *Fruit and vegetable processing*, FAO Agricultural Services.

Food and Agriculture Organization (2009). Available from *www.fao.org.*

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