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Opportunities in valorisation of industrial food waste into extruded snack products – A review

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ABSTRACT

Fruit and vegetable by-product production produces a large amount of waste material, which poses a significant disposal issue for the food industry and can have harmful effect on the environment, if left unused. This waste includes nutrients like dietary fibre, vitamins and minerals, as well as bioactive like flavonoids and lycopene. The functional and nutritional characteristics of by-products of fruit and vegetable processing, as well as their possible utilization in food extrusion technology as noble ingredients for enhancing the nutritional value in snack foods are the subject of this study. This review also proposes a method for producing a less expensive value-added ingredient, which reduces the current methods of disposing of these waste (that can have a negative impact on the environment) but still saving money for the manufacturer. The potential and opportunity for fruit and vegetable by-products incorporation in extruded snack products, thereby enriching the fibre and other nutritional components of the snack, is reflected in this paper. Ingredient industries are constantly searching for cheaper but value-added raw materials. So, this review will also enhance the horizon for not only the food industries but also encourage micro food entrepreneurs, the Self Help Groups and certain other domestic food enterprises in terms of the utility of the food waste, the methods of development and value added aspects as a whole.

Keywords: Extrusion technology, Fortified snack, Fruit and vegetable by-products, Industrial waste utilization

Extrusion cooking process is being used in the food industries for making ready-to-eat snacks from cereal source for breakfast cereals to baby foods (Sebio and Chang 2000). It has a diversified processing advantage as compared to the conventional processing methods. High product quality, automated control and high productivity, lesser processing space, no effluent, shorter response time, energy efficiency and perhaps most importantly, greater adaptability are among the advantages of this technology. Extrusion cooking processing provides a broad variety of processing methods for ready-to-eat healthy snack foods with ideal texture taste, flavour, and taste thanks to its diverse processing functions.

The main purpose of fruit and vegetable processing is to produce wholesome, safe, nutritious and tasty food to consumers all year round (Raleng *et al.* 2022). Vegetable and fruit by-products are plentiful, widely present in abundant amounts and are rated as providing greater dietary fibre content, high water binding capability, and a lower enzyme easily digested organic matter content (Serena and Kundsen 2007). Fruit by-products such as pineapple have been studied as a source of nutrition fibre supplementation in enriched and processed foods (Raleng *et al.* 2016). Dietary fibre helps to avoid diverticular diseases, heart disease and colon cancer (Maetinez-Flores *et al.* 2008). As a result, dietary fibre is really the third most coveted in markets in countries like Western Europe, India, North America and Australia (Mehta 2005). Resulting in high dietary fibre content, the co-products can also be used to change the physicochemical characteristics of diets.

Extruded snacks sold in India are usually developed from cereal flours and contain high protein, carbohydrate, and fat components. Healthy and therapeutic foods are in high demand among consumers these days, so snacks made from fruits and vegetable by-products might cater to that demand. Furthermore, the transformation of this waste into fibre-rich extruded snacks using a novel and flexible extrusion technique can be very beneficial both economically and in terms of health benefits. Extrusion processing is a viable method for using vegetable and fruit by-products because of its energy efficiency, flexibility, lack of effluents, low cost, and high productivity. Furthermore,

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since it will be made from food industry by-products, it can be produced at a competitive cost, far lower than what is currently available in the market.

Fruits and vegetables by-products

Through processing berries, vegetables and fruits, the fruits and vegetable sector produces a high amount of residual by-products. They are high in fibres and other phytochemicals and include pomace, cores, skins, roots, and seeds of berries and fruits. Using these by-products, which are rich in fibres and other phytochemicals, to complement various other food items, such as extrusion technology to produce fibre-rich food snacks, may be creative and a good idea towards safe, affordable, and nutritious food (Table 1 and 2).

Apple: Since apple pomace is a good source of pectin and a rich source of sugars, it can be used on a small scale to blend with low-pectin fruits to make jams, jellies and other foods that need extra pectin. Apple pomace has higher phenolic compounds and antioxidant properties, which combined with its high fibre, is one of the factors and it has been intensely researched as a promising food product in recent times (Cetkovic *et al.* 2008). Apple skin powder (ASP) is being used to increase the phenolic content of muffins. It was reported to boost antioxidant and phenolic value while also improving flavour (Rupasinghe *et al.* 2008). ASP from its variety Idared could be used as a wheat flour substitution in muffins, as per Rupasinghe *et al.* (2009). If wheat was substituted for 16% (weight basis [w/w]) ASP, sensory ratings remained desirable. The cakes also included apple pomace (AP), but the scientists reported that as the pomace amount rose above a certain extent, the cake volume reduced. Because of AP's water binding capacity; more water was necessary to completely moisten the dough. The researchers also discovered that the cake's colour deteriorated, as the level of AP in it declined.

Grape: Grape pulp is the press residue left after grapes are pressed for wine. Pressed skins, seeds, fragmented grape pulp cells and stems make up the pomace. Grape pomace is especially high in phenols, making it one of the most significantly available phenolic compounds amongst fruits (Meyer *et al.* 1998). Multiple studies have found phenolic compounds contained in grapes and wine contain antioxidant and health-promoting attributes, especially with regard to heart disease (Scalbert *et al.* 2005). As a result, grape pomace has the potential to be an effective source of phenolic antioxidants including technical applications as versatile food additive and beneficial effects. Grape pomace has a higher concentration of dietary fibre and related polyphenols (Valiente *et al.* 1995), indicating that it may be used as an ingredient in dietary fibre formulations (Martin-Carron *et al.* 2000).

Pineapple: Pineapple pomace is a waste product from the pineapple industry. Pineapple products and waste (heart and peel) contain approximately 76% fibre, 0.8% of which is soluble and 99.2% of which is insoluble (Martinez *et al.* 2012). Pineapple pomace, which is rich in dietary fibre, may be used as a dietary supplement to enhance the quality of food. Extrusion is indeed choice for using these by-products as materials in a particular agro-processing system. It can also help to reduce contamination associated with the disposal of by-products from the juice processing sector.

Blackcurrant: Currant seeds are rich in stearidonic acids, a-linolenic, and g-linolenic, all of which are good for your skin and can help with atopic dermatitis syndrome (Johansson *et al.* 1997). Colorants and anti-browning substances, antimicrobial compounds to extend shelf life, and flavouring components are all possible side-stream exploiters (Viuda-Martos *et al.* 2010, Ayala-Zavala *et al.* 2011). Compounds of phenolic or seed oil fraction may be beneficial to the food and pharmaceutical applications (Sandell *et al*. 2009, Wijngaard *et al.* 2012).

Carrot: Carrot pomace is a waste product of the carrot juice manufacturing process. Carrots are a root vegetable. Carrot juice yield varies between 60 and 70%, and residual carrot pomace can loss up to 80% of its carotene content (Bohm *et al.* 1999). It also has a healthy dose of minerals, dietary fibre and vitamins. The pomace is highly perishable since it contains around 88.2% moisture. Durrani *et al.* (2011) investigated whether carrot could be used as the primary component in a honey-based candy. As per the scientists, the product earned good sensory scores along with satisfactory physicochemical and microbial performance. It was observed that the commodity could be stored safely at 25–30°C for 6 months considering the nature of its manufacturing.

Tomato: Tomato pulp is a side product of tomato production. This by-product makes up less than 4% of the fruit's overall weight (Del *et al.* 2006). The dry and smashed skins & seeds of tomatoes compose tomato pomace (Tadeu-Pontes *et al.* 1996). Lycopene, an essential ingredient, is found in the tissues of pomace. Lycopene is a natural food pigment that often serves as a functional component, providing significant various health benefits (Kaur *et al.* 2005). Tomato peel was successfully applied to hamburgers to increase nutritional quality in the existence of lycopene. The only drawback was that the colour of the hamburgers changed, causing the meat to turn brown. This is attributed to the large concentration of carotene pigment in hamburgers (Luisa *et al.* 2009).

Lemon: Citrus pulp is a processing residue of juicy citrus fruits like grapefruit, lemons and oranges. Lemon, like many other citrus fruits, is rich in polyphenol and antioxidant level. As per Marn *et al*. (2002), lemon juice is very high in vitamin C. Ascorbic acid is thought to help with iron absorption, hormone production, and cell oxido-reduction processes. Carotenoid was another phytochemical present, but it was not as common as the flavonoids. Numerous scientific papers, on the other hand, have emphasised the beneficial effects of the by-possible product. As per Gorinstein *et al.* (2001), dietary fibre value in peeled fruit is 7.34 g/100 g DM as compared to 14 g/100 g DM in lemon peels itself. Dietary fibre was divided into two types: soluble (4.93 g/100 g DM) and insoluble (9.04

g/100 g DM). The lemon peel is also a rich source of iron, according to the researchers.

Orange: An orange is a tasty, healthy, and pulpy fruit. It has a distinct appearance, smell and taste. In terms of calories, it is amongst the most extensive sources of vitamin C amongst vegetables and fruits. Besides vitamin C, it also includes sugar, essential oils, carotenoids, fibre, flavonoids and a few minerals (Niu *et al.* 2008). Oranges are usually eaten as fresh orange juice, pasteurised orange juice or concentrate juice. In certain recipes, it's often used as vegetable flavouring or seasoning. 85% of oranges are turned into orange juice after fermentation, resulting in tonnes of solid waste. This waste is normally fed to livestock or discarded at the producer's expense (Topuz *et al.* 2005). Chau and Huang (2003) studied the dietary fibre content of orange peel (cv. Liucheng). The peel has a total dietary fibre content of 57% DW, with 9.41% DW soluble and 47.6% DW insoluble. Because the insoluble component is the most common, it has health benefits such as increased intestinal performance and better stool volume. Cellulose and peptic polysaccharides were identified to be the key components of the fibre.

Cauliflower: Cauliflower has a high waste index (Kulkarni *et al.* 2001), and it is high in cellulose (16%), protein (16.1%) and hemicellulose (8%) (Wadhwa *et al.* 2006). It has antioxidant and anti-carcinogenic properties and is a healthy source of dietary fibre. Vitamin C and phenolic compounds, which have a higher concentration and antioxidant activity, are the key antioxidants in brassica vegetables (Podsedek 2007).

Potato: Potatoes are high in carbohydrates, dietary fibre, phenolic compounds and minerals, all of which contribute to their nutritional value (Abu-Ghannam and Crowley 2006). As a result of the processing and preparation of potatoes, tonnes of potato pulp and peel are produced, offering the possibility of new ways of disposing of or use this by-product. Since potatoes contain fibre and starch, using them as an unique food product could provide beneficial properties such as gelling and additional nutritional benefits to commodities, such as bakery products and fresh meat pastes (Kaack *et al.* 2006).

The result of adding potato peel into a wheat bread formulation was studied by Kaack *et al.* (2006). Solubilized potato peel fibre decreased the bread's stiffness and gumminess. At 12% amount of addition, the potato peel fibre (solubilized) earned desirable sensory values from the professional panellist. And in potato peel fortified bread, the level of dietary fibre was raised from 10.8–17.5%.

Physico-chemical properties of the extruded snack developed from fruits and vegetables by-products

Caltinoglu *et al.* (2013) investigated the effects of tomato pulp addition on extrudate consistency parameters as well as the effects of extrusion on extrudate functional properties. There was no noticeable difference in bulk density, longitudinal expansion index, volume expansion index, or

Table 1 Review of industrial fruits waste used in extruded snack products

Fruit/Vegetable	Parameter	Response	Inference	Reference
Grapes	Die temperature (140–160°C), Screw speed (150–200 rpm), Pomace level (2–10 db)	Expansion, Bulk density, Texture, Colour, Sensory analysis	Blends of 2% grape pomace extrude at 160°C, 200 rpm and 10% grape pomace extruded at 160°C, 150 rpm has the highest sensory preference.	Altan *et al.* (2008)
Tomato	Die temperature (140–160°C), Screw speed (150–200 rpm), Pomace level (2–10 db)	Expansion, Bulk density, Water absorption and solubility indices, texture, color	Product responses were most affected by changes in temperature and pomace level and to lesser extent by screw speed.	Altan *et al.* (2008)
Lemon	Extrusion temperature (59.77–110.63°C), Screw speed (3.18–36.82 rpm), Moisture content (33.18–66.82 %)	Dietary fibre	The highest content of soluble fibre was 50.00% when operating conditions were high in temperature (100°C), low in moisture content (40%) and low in screw speed (10 rpm).	Mendez-Garcia *et al.* (2011)
Banana	Banana flour (BF), Screw speed (SS), Extrusion temperature (ET)	Color, Expansion, Flextural strength	Addition of BF resulted in higher L* and lower a* and b* values. Expansion increased with increase in the level of BF and ET. Flextural strength increased with increased in SS followed by BT and ET.	Kaur *et al.* (2015)
Pineapple	Moisture content, MC (17–21%), Screw speed, SS (260–340 rpm), Die temperature, DT (120–140°C)	Lateral expansion (LE), Bulk density (BE), Water absorption index (WAI), Water solubility index (WSI), Hardness.	Increase in DT resulted in higher LE, hardness, WAI and lower BD, WSI. Increase in SS resulted in higher LE, overall acceptability (OA) and lower BD, hardness.	Kothakota *et al.* (2013)

Table 2 Review of industrial vegetable wastes used in extruded snack product

Fruit/Vegetable	Parameter	Response	Inference	Reference
Cauliflower	Moisture content (9–11%), Screw speed (250–350 rpm), Die temperature (80–120°C)	Nutritional and Textural characteristics	Addition of cauliflower significantly increased the dietary fibre and levels of proteins. The expansion indices showed negative correlation to the level of cauliflower.	Ibanoglu (2008)
Broccoli	Screw speed (150 rpm, 200 rpm, 250 rpm), Die temperature (140°C, 160°C, 180°C), Moisture content (14.5%, 16.5%, 19.5%), broccoli concentration (4%, 7%, 10%)	Structural properties and Rehydration	Increase in moisture content, broccoli concentration and decrease in die temperature and screw speed resulted in denser extrudates with lower porosity.	Bisharat *et al.* (2013)
Carrot	Screw speed (300–500 rpm), Die temperature (120–180°C), Moisture content (14–20 %), Feed ratio (rice flour: pulse flour: carrot pomace powder- 60–80%: 10–30%: 10%)	Protein, Fibre, Color, Texture, Overall acceptability	The optimized condition using parameters for screw speed, die temperature, moisture content and rice proportion were 340 rpm, 120°C, 20% and 60% respectively.	Alam *et al.* (2013)
Potato	Feed moisture (12.6–19.4%), Screw speed (349–601 rpm), Barrel temperature (116–184°C)	Specific mechanical energy (SME), Bulk density (BD), Water absorbency index (WAI), Water solubility index (WSI), Hardness	Increase in feed moisture reduces SME and WSI and increases BD, WAI and hardness. Increase in screw speed decreases the BD, WAI and hardness of the snacks, whereas increase in barrel temperature decreases the SME, BD, WAI and hardness but increases the WSI.	Singh *et al.* (2014)
Pea	Protein content (6%, 12%, 18%), Moisture content (15%, 18%, 21%, wb), Temperature (100°C, 120°C, 140°C)	Expansion, Hardness, Particle density	Extrusion of pea flour containing 6% protein and 15% moisture at a set temperature of 120°C resulted in expansion indices (EIs) of 3.3 and 3.6, respectively. EI decreased, and extrudate bulk, particle densities and hardness increased with increase in protein or moisture content.	Shannon *et al.* (2010)

porosity between extrudates with and without tomato pulp. With the addition of pulp, the sectional expansion index increased slightly. Textural analysis revealed that the stiffness and fracturability of extrudates with and without pulp did not differ significantly. Tomato pulp can also be used as dietary supplement in the development of new functional extruded foods, according to the studies. Hong *et al.* (2014) used answer surface methods to find the best extrusion conditions for developing the best quality puffing health food using pumpkin powder blended with corn flour. The mixing ratio of pumpkin powder to corn flour (10:90, 20:80, 30:70), and even the moisture content of the mixing raw material and the extruder screw speed (250–380 rpm), both influenced the extrusion process. Pumpkin flour level, moisture levels, and screw speed were all minimized by 19–21%, 11.5–12.5% and 275–288 rpm, respectively, as a result of the graphical optimization process.

Kaur *et al* . (2015) examined the influence of extrusion conditions (banana flour, screw speed and extrusion temperature) on the extrusion performance of corn grit extrudates. 2nd order quadratic equations were used to measure extrusion properties as a function of banana flour (BF), extrusion temperature (ET) and screw speed (SS). BF had the greatest impact on the extrudates' Hunter colour (L*, a*, b*) conditions. The L* value increased when BF was applied to corn grits, whereas the a* and b* values decreased. Higher ET extrudates had darker colours and lesser L* and a* values. The extrudates' lightness was increased by increasing the SS. As the concentrations of BF and ET increased, so did the expansion of the extrudates. With BF, the WAI of the extrudates reduced, but with SS, it increased.

Application of fruits and vegetable by-products in extrusion studies of extruded snack

The impact of input moisture (18–24%), extrusion temperature (130–170°C) and pea grits composition (0–30%) on rice grits extrusion interaction and extrudate attributes were evaluated by Singh *et al.* (2007). Extruder die pressure, density, expansion ratio, water absorption index, real energy consumption and water solubility index were all studied. Second-order polynomials were used to correlate extruder variables and product attributes as a measure of feed moisture, extrusion temperature and pea grit number.

Mendez-Garcia *et al.* (2011) modified an extruded substance made with lemon extracts to increase the soluble fibre segment. A response surface procedure with 6 central points and six axial points was used to assess changes in dietary fibre concentrations in lemon remnants. The control variables examined were extrusion temperature (9.77–110.63°C), sample moisture levels (from 33.18–66.82%), and screw speed (3.18–36.82). In extruded products, the soluble fibre proximate composition of unprocessed lemon extracts raised from 38.60–50.01%. The highest content of soluble fibre recorded 50% when operating conditions were elevated in temperature (100°C), low in moisture level (40%), and low in screw pace (10 rpm). Kumar *et al.* (2012) chose a polyethylene sealing device to seal extrudates (25 g) in LDPE pouches and aluminium laminated LDPE pouches within optimal proportions (rice flour, pulse powder and carrot pomace), moisture levels, screw speed, as well as die temperature. The bags were then held in an incubator for six months at a temperature of 382°C to test the product's stability. Colour, hardness, moisture content, and sensory characteristics of the extrudates were all examined. Aluminium laminated LDPE bags showed the least overall improvement in colour E value, the least increase in moisture content, and the least increase in hardness.

Makila *et al.* (2014) investigated extrudates produced using blackcurrant press residues (30%), cereal products (40%) and potato starch (30%), as well as a small quantity of salt and sugar. The new non-enzymatic press residual extruded from barley or oat flour provided higher expansion, lower hardness and density, increased redness (a*), lower *p*H and ensured growth of fructose, glucose, and fruit acids than enzymatic press residue and oat bran, all of which attributed to berry-like texture, appearance and taste. The research revealed a long-term approach for repurposing industrial press residues from different berry juice pressing techniques into healthy snacks and breakfast cereals.

Textural and microstructural studies on extruded snack products

Well before extrusion, Parada *et al.* (2011) analysed the microstructure, physicochemical parameters (texture, expansion, density, pasting), and nutritional composition of guar gum (0–10%) subjected to a flour mixture (maize, potato, rice, and wheat) (starch digestibility). Guar gum did not reduce starch digestibility rather, it increased starch digestibility by 24%, 15% , 25% and 43% in maize, potato, rice and wheat flour-based products, respectively, at a concentration of 10%. Increase in starch digestibility tend to be linked to extrudates containing guar gum having a weaker microstructure, a greater matrix surface region, and a lower viscosity. Noorakmar *et al.* (2012) used a Field Emission Scanning Electron Microscope to examine the effects of adding orange sweet potato flour to tapioca starch on microstructure properties (FESEM). The product's form and texture were close to that of a typical breakfast cereal. The addition of orange sweet potato flour to tapioca starch in the fried extruded fish crackers resulted in a soft brownish and slightly harder texture. According to the microstructure tests, fried extruded fish crackers with a higher percentage of orange sweet potato flour had small air cells and a thick cell wall, which is contrary to the desired consistency of the fried cracker. The educated panellists praised the crispiness of the fried extruded fish crackers, which contained 30% fish, 14% orange sweet potato flour, and 56% tapioca starch.

Kasprzak *et al.* (2013) studied the microstructure and physical properties of corn extrudates using high-fibre ingredients (everlasting pea whole meal, oat bran). The effects of material blend composition and variable process parameters such as material blend moisture (11, 13.5, 16%) and barrel temperature distribution profile (120/145/115, 130/155/115, 140/165/115°C) on the microstructure and physical properties of extrudates were investigated. Both the material composition of the blend and the process parameters affected the microstructure of the products. Extrudates' physicochemical characteristics and sensory attributes can be altered in a range of ways, based on differences in air cell size, number of shapes and cell wall thickness.

Application of frying, packaging and storage studies on extruded snack products

Deep-fat fried extruded products made from cereals, legumes, and their blends, which are widely consumed due to their appealing organoleptic profile, were investigated by Annapure *et al.* (1998). Grain types differ in chemical make-up and physicochemical properties, which may explain why extruded snacks have varying levels of oil. In addition, the frying medium has an effect on the amount of oil used in deep-fat frying. Saeleaw and Schleining (2011) investigated cassava crackers made from cassava starch, water and deep-fried in oil at 140, 150, and 160°C. Moisture content, bulk density, linear expansion, sound emission, and penetration forces of cassava crackers were optimised at 5, 10, and 15 sec of the frying phase. The results show that as the frying time and temperature increase, the moisture content, number of force peaks, linear expansion, and sound peaks all raise, while the density, maximum and mean force peaks fall. It was also discovered that as the temperature rose, the number of small air cells increased.

Dar *et al.* (2014) fried extrudates at temperatures of 170, 180, 190, and 200°C for 5, 10, and 15 sec using optimised flour proportions (rice flour, pulse powder and carrot pomace), moisture contents, screw pace and die temperature. The chosen product was wrapped in metalized polypropylene and stored for 6 months before being tested for free fatty acid, peroxide value, crispiness, stiffness, colour and beta carotene based on sensory characteristics. Increasing the frying temperature and time resulted in an increase in colour L-values, b-values, oil absorption and a decrease in colour a-values in carrot pomace-based rice extrudates. The customer preferred and gave a higher rating to the snack that was baked for 15 sec at 180°C.

Raleng *et al.* (2019) investigated the bioactive properties of extrudates containing ready-to-eat pineapple pomace powder. Deep-fried extrudates were prepared under optimised extrusion processing parameters and deep-fried at 160–180°C for 5–15 sec in rice bran oil. Extruded snack fried for 15 sec at 180°C had the highest acceptability (6.33), the lowest hardness (9.59 N) and the best colour value. In terms of free fatty acid increase (0.65%), peroxidase value (4.23 meq/kg) and colour value "L," "a," and "b" retention, the results showed that ACL packaging content was more effective. Extrudates wrapped in ACL packaging material lasted four months and retained their consistency better.

Application of response surface methodology for process optimization of the extruded snack

The effects of die temperature (65–125°C), feed rate (2.5–8.5 g/s), feed moisture (10–30% wb), and carrot pulse pomace (1.5–15.5% wb) on extrudate moisture, bulk density, expansion index, and sensory characteristics were investigated using response surface methods by Upadhyay *et al*. (2010). An optimization of process variables was attempted using a regressed equation to achieve optimum desirability in responses. The best carrot pulse pomace concentration was found to be 5%, with a 7.4 overall acceptability score. According to the study, CPP integration could result in a suitable extruded product.

Alam *et al.* (2013) investigated the effect of die temperature (120–180°C), screw speed (300–500 rpm), moisture content (14–20%), and ingredient proportion (rice flour: pulse flour: carrot pomace powder- 60–80%: 10–30%: 10%) on protein, fibre, colour, texture, and overall acceptability of extruded products using Response surface methodology (RSM). Using selective consistency parameters, the ideal operating conditions for screw speed, die temperature, moisture content and rice proportion in ingredient composition were 340 rpm, 120°C, 20%, and 60%, respectively. According to analysis of variance (ANOVA), sample formulation had the most important effect on all responses, followed by screw speed; die temperature and moisture content had a slightly higher effect on overall acceptability and hardness.

Chiu *et al.* (2013) used response surface methods to look at the best operating conditions for a single screw extruder and the effects of extrusion processing variables including yam flour content (10–30%), feed moisture (10–18%), and screw speed (250–350 rpm) on the characteristics of corn-yam extrudates (RSM). The water absorption index, bulk density, and hardness all increased as moisture content increased, but the radial expansion ratio decreased. Graphical optimization tests, on the other hand yielded yam flour levels, moisture content, and screw speeds of 21–23%, 12–13%, and 305–320 rpm, respectively. According to the findings, corn extrudates fortified with yam can be used to produce snack foods.

Many reusable substances with high nutritional value can be included in the waste from fruits and vegetables. These cannery wastes have a high exploitation potential and a bright future. Producers are often searching for more quality, high-value materials, and processing from fruit and vegetable by-products may be a good fit. Dietary fibre is commonly recognised as an essential ingredient in the human diet. Fruit and vegetable by-products have been shown to be a good source of dietary fibre in studies. Furthermore, health consciousness of people is increasing, so supplementing food with the necessary nutrients from low-cost sources may be a good choice to meet the rising demand.

This research explores options for repurposing by-products from fruit and vegetable processing into extruded snacks in a sustainable manner. As a result, extrusion technology is being used to turn waste from fruit and vegetable by-products manufacturing plants into a low-cost nutritious dietary supplement for low-income communities. Overall, the research shows that by-products from different fruit and vegetable production can be used to satisfy the increasing demand for healthier ready-to-eat foods.

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