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EXTRUDED PRODUCT WITH BLACKBERRY SEED BY-PRODUCT: ECO-FRIENDLY SUSTAINABLE APPROACH TO UTILIZE BIOACTIVE COMPOUNDS

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The exponential population growth and increasing consumer demands for healthy functional foods lead to the dire need for exploration of sustainable phytochemical rich sources. In-depth research on zero-waste food processing through food by-product utility may occupy a promising solution as an eco-friendly method through minimizing the environmental adverse consequences associated with the disposal of food waste. Extruded snack food products being efficient in producing wide variety of innovative value addition and contributes valorization to the agro-industrial waste. Murukku, the traditional Indian savoury is an extruded product suitable to incorporate dehydrated functional food waste powders as appropriate tool for effective bioactive compounds utilization. Blackberry seeds are one of the healthy choices among food waste by-products being rich in antioxidants, dietary fiber, phenolic compounds offering significant nutritional and health benefits to reduce the incidence of chronic disease conditions. Based on this background, the current investigation was aimed at the development of black berry seed based extruded product in the form of murukku. Three different trials were formulation with the major ingredients as rice flour, besan flour, black gram dhal, moong dhal and blackberry seed powder. They were subjected to organoleptic evaluation to test the acceptability of the formulated trials. The panel mean organoleptic scores indicated high acceptability for the portioning of 40:20:20:5:15 in the respective major ingredients. The findings well demonstrated the blackberry seed based murukku as nutritious ready to eat snack owing to good source of protein, fat, crude fiber, calcium and iron. Being low in moisture content might be beneficial in extending shelf stability of the product and ensures quality and safety of the product due low water activity in the product. Promotion of such bioactive food by-products may be an invaluable approach to mitigate protein energy malnutrition in the children and chronic diseases among adults as well as to target for public health and sustainable development goals.

Keywords: Blackberry seed, Food waste, By-products, Environment, Eco-friendly Extruded products, Murukku, Sustainable, Functional foods

Introduction

The extrusion process is extensively utilized in the agri-food sector and considered as food extrusion or extrusion cooking. The "extrusion" terminology is actually derived from the Latin word ‘extrude’ means "to thrust out" or "force out. Extrusion method comprised of forcing combination of raw materials through desirable sized apertures or die under pressure to shape the food materials under HTST (High temperature short time) method ((Prabha et al., 2021). The principles of extrusion process include heat and mass transfer, alterations in pressure, exerting shear forces to produce food complex transformations like starch gelatinization, protein hydration, homogenization, protein denaturation and re-orientation with favourable structural expansion in the food (Yadav et al., 2025). The technology holds popularity in the production of variety of snack foods, breakfast cereals, modified starch foods, pet foods, traditional food products etc. Recently, promotion of traditional foods is of focus to impart indigenous identity, influence consumer behaviour through transfer of local food cultural heritage to the future generation. Murukku is a popular familiarized ethnic Indian snack especially in South Indian cuisine using extrusion technology and thus recognized as extruded traditional snack food (Bhosale et al., 2021). This extruded product not only demonstrates the indigenous creativity but may be easily adopted for introducing different functional foods. It serves as incremental technology to attain sustainable development goals (SDGs) through bringing into sustainability and protect ecosystem through incorporation of food waste which is of major concern.

The agro-food industry generates huge amounts of food waste while employing diverse unit operations from different sectors such as fruit, vegetable, cereal, dairy, beverage industry etc. The unwanted food waste can be turned into by-products and can enhance utility through effective utilization as they are rich in phytochemicals like carotenoids, phenols, phytoesterols, essential fatty acids, antioxidants, dietary fiber, essential nutrients especially micronutrients of vitamins and minerals etc (Di Lorenzo et al., 2021). The versatile and cost-effective affordable extrusion technology occupies unique position to bring value addition to the industrial food by-products to formulate and introduce variety in extruded products. Interestingly, this technique brings desirable changes in food textural, organoleptic, physical, functional and nutritional characteristics (Mironeasa et al., 2023). Simply, it serves as a precious tool to attain the sustainable development goals through providing good health wellbeing, promoting environmental conservation by bringing utility to the unconventional under-utilized food sources and by-products yielded in the food processing system. Integrating into the regular industrial food sectors certainly enhances processing value, grabs healthy attitudinal consumer behaviour and to reproduce as profitable marketing (Sule et al., 2024).

Blackberry is mainly consumed as fresh but at industrial applications, it is used in the production of jams, juices, syrups and liqueurs producing greater quantities of seed accounting around 80 per cent as by-product. Rich phenolic compounds present in the seed exert excellent antioxidant capacity providing effective gastrointestinal digestion through modulating intestinal micro-biota (Rivero-Perez et al., 2024). The associated oil content in the seed is the crucial factor for exhibiting bioactive antioxidant properties owing to the fatty acid composition as phytosterols including lipophilic constituents in the form of vitamins E and A (Blejan et al., 2023). It is helpful commercially in making food additives as natural emulsifier,

bulk agent, preservative, thickener and colorant which would be significant alternative to the synthetic additives (Cechoviciene et al., 2024;Krivokapic et al., 2021).

The seed protein being phyto-origin typically possess numerous health benefits due to its antioxidant capacity, immune protectiveness, anti-hypertensive, anti-hyperlipidemic and anti-proliferation properties (Kumoro et al., 2020). These unique beneficial properties not only promote better health but also minimizes the risks of chronic conditions such as cardiovascular diseases, hypertension, various types of cancers, autoimmune disorders etc (Wang et al., 2023; Morinet al., 2022).

Methodology

The current study aimed at the development of blackberry seed based extruded product to utilize the potential functional and health benefits of the seed. Blackberry seed powder was prepared by separating the seeds after separating the pulp from the fruit. The seeds were dehydrated at 60^0c in hot air oven till complete removal of moisture. The dried seeds were ground into fine powder in the grinder and stored in airtight container for further use in the formulation of extruded product.

The traditional extruded product, murukku was chosen to incorporate blackberry seed powder and standardized in the three different trials. The major ingredients used in the preparation of blackberry seed based murukku were rice flour, besan flour, black gram dhal, moong dhal and blackberry seed powder. The black gram dhal and moong dhal were roasted separately till pleasant aroma was obtained, ground to fine flour and utilized as per the required proportion based on variations. Chili powder, ajwain and salt were added to enhance the taste, made into dough using water, divided into small balls, placed in manual murukku mould, extruded through the perforated plate under pressure of desirable size and shape and subjected to deep fat frying in the pre-heated oil. The composition of major ingredients for the three formulated trials was provided in table 1.

Table No-1: Composition of the three formulations for the development of blackberry seed based extruded product (Murukku)

S.No.	Ingredients	T_1	T_2	T_3
1	Rice flour	35	40	35
2	Besan flour	15	20	20
3	Black gram dhal	20	20	15
4	Moong dhal	20	5	5
5	Blackberry seed powder	10	15	25

The acceptance of the three trials was evaluated through organoleptic evaluation using nine-point hedonic rating scale with a panel of 30-members. The trial which had scored the maximum acceptability mean scores was treated as the standardized trial for the development of blackberry seed based extruded product. The nutrient analysis was carried for the essential nutrients viz., moisture, protein, fat, crude fiber, calcium and iron as per the standard protocols.

Results and discussion

The organoleptic parameters studied while organoleptic evaluation were appearance, colour, odour, taste, texture, after-taste and overall acceptability. The mean scores of the three trials

for each organoleptic parameter were presented in the table 2 and the overall acceptability was illustrated graphically in figure 1.

Table No-2: Mean organoleptic scores of the three formulations for the development of blackberry seed based extruded product (Murukku)

S.No.	Organoleptic Parameter	T_1	T_2	T_3	F-Value	P-Value
1	Appearance	8.20±0.76	8.57±0.50	7.07±0.74	39.86595	<0 .00001*
2	Colour	8.33±0.55	8.53±0.51	6.43±0.94	84.48434.	<0 .00001*
3	Odour	8.23±0.63	8.33±0.66	8.13±0.73	0.66076	0 .519031^{NS}
4	Taste	8.17±0.65	8.37±0.61	7.13±0.82	26.84429	<0 .00001*
5	Texture	8.20±0.61	8.40±0.62	7.80±0.61	7.42683	0.001052*
6	After-taste	8.10±0.66	8.17±0.87	6.13±1.01	54.13834	<0 .00001*

Note: * - Significant at 1 % level; ^{NS}- Not significant

The results from the table on mean organoleptic scores well demonstrated that the trial T_2 had scored the maximum mean organoleptic scores irrespective of the organoleptic parameter, then followed by T_1 and the least by the trial T_3. The difference found to be highly significant at 1 per cent level for all organoleptic parameters except odour which had not showed any significant differences. However, the trend of results represented similar pattern with the mean score for T_2 trial and the lowest for T3 trial. The proportion of 40:20:20:5:15 of rice flour, besan flour, black gram dhal, moong dhal and black berry seed powder seemed to be a highly acceptable and successful combination. The higher proportion of rice flour in the second trial had provided the desirable crispy texture probably the rice flour being gluten free contributes to crispiness instead of elasticity and chewiness, quick dehydration of gelatinized starch granules on frying and absorbs less oil lead to characteristic crunchy and non-greasy murukku texture. The besan flour also contributed favorable impact on textural characteristics with sufficient binding capacity and softness without hardiness. The higher proportion of blackberry seed powder about 25 per cent in the third trial was not suitable due to the resultant dark brown colour, eventually the appearance was also affected and observed with poor after-taste. Reduction in the rice flour quantity for the proportionate increase in the seed powder might shown little adverse effect on texture. All these had influenced the acceptance levels of the third trial murukku with relatively low mean organoleptic scores.

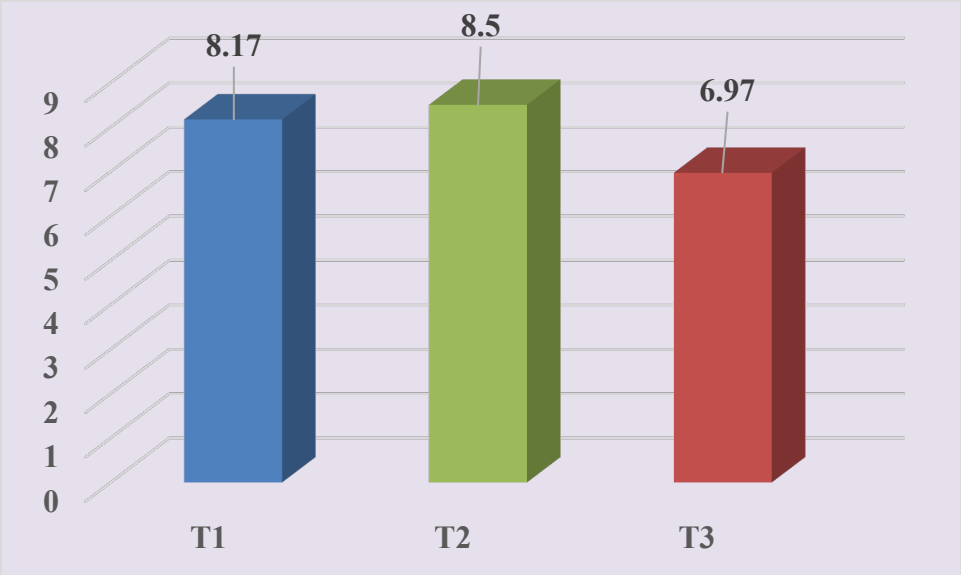

Figure No-1: Overall acceptability mean scores of the three formulations for the development of blackberry seed based extruded product (Murukku)

The illustrations from the figure clearly represented the highest overall acceptability of the second trial as reflected by the mean organoleptic scores among the three formulated trials. The first two trials were within acceptable range but the third trial scored the least overall acceptability scores and found to be not much accepted indicating the acceptability of blackberry seed powder to the level of 15 per cent with proportionate increase of rice flour. The findings thus explained that correct portioning of ingredient combination is crucial to ensure pleasant harmonious blend and flavour. Especially in fried extruded foods like murukku, the physico-chemical changes such as appropriate starch gelatinization and emulsification aided in yielding delicious end product, enhancing consumer satisfaction and simultaneously profitable marketing.

The nutrient composition analyzed in the standardized blackberry seed based extruded product as murukku for the essential nutrients was presented in table 3.

Table No-3: Nutrient composition of the standardizedblackberry seed based extruded product (Murukku)

S.No.	Nutrient	Quantity
1	Moisture (g)	7.32
2	Protein (g)	16.34
3	Fat (g)	26.93
4	Crude fiber (g)	6.47
5	Calcium (mg)	86.63
6	Iron (mg)	3.72

Murukku being deep fat fried food resulted in driven off the higher quantities of water from the dough, the heated oil quickly made to evaporate surface and internal moisture content and thus showed low moisture content around 7.32 g. The dhal flours used in murukku making had provided good amounts of protein about 16.34 g and rich source of fat (26.93 g) due to deep fat frying. Basically the grains had considerable quantity of crude fiber and in fact, it might be enhanced with the incorporation of blackberry seed powder to the extent of 6.47 g. The

developed extruded product was also found to be rich in micronutrients as evidenced by 86.63 mg of calcium and 3.72 mg of iron.

Vega-Castro et al., 2024 had prepared spray-dried blackberry powder which was enriched with zinc and folate could able to met nearly 30 per cent of daily nutritional requirements with 50 g proportion. Promotion of research and encourage for practical implementation might be helpful to address the nutritional deficiency problems especially among the vulnerable sections of pregnant and children. Exploring maximum of research in this area could be beneficial to achieve SDG-2 (Zero Hunger) and SDG-3 (Good Health and Well-being) through extending the food waste utility as well as health and functional benefits of antioxidants and phyto-chemical constituents (Zou et al., 2021; Banwo et al., 2021; Bhat 2021).

Conclusion

The extrusion technology had gained great popularity owing to its convenience, versatility and ease in producing variety of ready to eat foods. The current investigation had emphasized on standardization of blackberry seed based traditional murukku and tested for the proportionate incorporation of seed powder. The study demonstrated successful innovative solution to utilize the blackberry seed by-product to enhance health promoting properties through the promising potential bioactive phytochemical constituents like antioxidants, essential fatty acids, dietary fiber and essential nutrients. Encouraging fruit waste products found effective mode of improved functional and nutritional profiles to produce health promoting value added functional food products. The consumers demand on nutritious RTE foods had gained momentum in food industry and become effective sustainable approach to environmental protection and reach as part of sustainable development goals.

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References

- Banwo, K.; Olojede, A.O.; Adesulu-Dahunsi, A.T.; Verma, D.K.; Thakur, M.; Tripathy, S.; Singh, S.; Patel, A.R.; Gupta, A.K.; Aguilar, C.N. Functional Importance of Bioactive Compounds of Foods with Potential Health Benefits: A Review on Recent Trends. *Food Biosci.* 2021, 43, 101320.
- Bhat, R. Chapter 1—Sustainability Challenges in the Valorization of Agri-Food Wastes and by-Products. In *Valorization of Agri-Food Wastes and By-Products*; Bhat, R., Ed.; Academic Press: Cambridge, MA, USA, 2021; pp. 1–27.
- Bhosale, S.S.; Agarkar,B.S.; Kshirsagar, R.B.; Patil, B.M. Studies on technology for preparation and quality evaluation of multigrain extruded product chakli. *The Pharma Innovation Journal* . 2021; 10(7): 1593-1596.
- Blejan, A. M.; Nour, V.; Pacularu-Burada, B.; Popescu, S. M. Wild bilberry, blackcurrant, and blackberry by-products as a source of nutritional and bioactive compounds. *International Journal of Food Properties*, 2023, *26*(1), 1579–1595. https://doi.org/10.1080/10942912.2023.2224530.
- Cechoviciene, I.; Viskelis, J.; Viskelis, P.; Hallman, E.; Kruk, M.; Taraseviciene, Z. Potentially Bioactive Compounds and Sensory Compounds in By-Products of Several

Cultivars of Blackberry (*Rubusfruticosus* L.). *Horticulturae*, 2024, 10(8), 862. https://doi.org/10.3390/horticulturae10080862.

- Di Lorenzo, C.; Colombo, F.; Biella, S.; Stockley, C.; Restani, P. Polyphenols and human health: The role of bioavailability. *Nutrients,* **2021**, *13*, 273.
- Krivokapic, S.; Vlaovic, M.; DamjanovicVratnica, B.; Perovic, A.; Perovic, S. Biowaste as a Potential Source of Bioactive Compounds—A Case Study of Raspberry Fruit Pomace. Foods, **2021**, 10, 706.
- Kumoro, A.C.; Alhanif, M.; Wardhani, D.H. A Critical Review on Tropical Fruits Seeds as Prospective Sources of Nutritional and Bioactive Compounds for Functional Foods Development: A Case of Indonesian Exotic Fruits. *Int. J. Food Sci.,* 2020, 4051475.
- Mironeasa S,; Coţovanu I,; Mironeasa C,; et al. A review of the changes produced by extrusion cooking on the bioactive compounds from vegetal sources. *Antioxidants*, 2023;12(7):1453.
- Morin, P.; Howard, L.R.; Tipton, J.; Brownmiller, C.; Mauromoustakos, A.; Threlfall, R.T.; Clark, J.R.; Worthington, M. Phenolics and Volatiles in Arkansas Fresh-Market Blackberries (Rubus subgenus Rubus Watson). *ACS Food Sci. Technol.,* 2022, 2, 1728–1737.
- Prabha K.; Payel G.; Abdullah S.; Joseph, R.M.; Krishnan, R,; Rana, S.S.; Pradhan, R.C. Recent development, challenges, and prospects of extrusion technology, *Future Foods*, 2021, 3, 100019.
- R. Zou et al., Maternal folate levels during pregnancy and offspring brain development in late childhood. *Clin. Nutr*., 2021, 40,3391–3400 , https://doi.org/10.1016/j.clnu.2020.11.025.
- Rivero-Perez, M. D.; Gerardi, G., Cavia-Saiz, M., Ortega-Heras, M., & Muniz, P. The Bioactivity of Byproducts from the Blackberry (*Rubusfruticosus*) Juice Industry. *Biology and Life Sciences Forum*, 2024, 40(1), 52. https://doi.org/10.3390/blsf2024040052.
- Sule,S.; Okafor,G.I.,;Momoh,O.C.; Gbaa,S.T.; Amonyeze, A.O. Applications of food extrusion technology. *MOJ Food Processing & Technology* 2024, 12(1), 74-84.
- Vega-Castro, O.; Diego, VM.; Santiago, CT. et al. Exploring the Potential of Spray-Dried Blackberry Powder Enriched with Zinc and Folic Acid as a Nutritional Alternative for Children and Pregnant Women. *Food Biophysics*, 2025, 20, https://doi.org/10.1007/s11483-024-09892-0.
- Wang, S.; Zhao, F.; Wu, W.; Lyu, L.; Li, W. Proteins from Blackberry Seeds: Extraction, Osborne Isolate, Characteristics, Functional Properties, and Bioactivities. *International Journal of Molecular Sciences*, 2023, 24, 15371. https://doi.org/10.3390/ijms242015371.
- Yadav, N.; Suvedi, D.; Sharma, A.; Khanal, S.;Verma, R.; Kumar, D.; Khan, Z.; Peter, L. Extrusion technology in food processing: Principles, innovations and applications in sustainable product development, *Food and Humanity*, 2025, 5, 100672, https://doi.org/10.1016/j.foohum.2025.100672.