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Development of Nutritionally Dense Vegetable Pomace with Chickpea Flour Crackers for Children and Adolescents

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ABSTRACT

The growing need for healthily nutritious snack food and the pressing need to alleviate food wastage have triggered interest in the use of agro-industrial by-products for innovative food development. This research aimed at the ingredients and quality assessment of crackers produced from vegetable pomace carrot and beetroot pomace and blended with chickpea flour. Carrot and beetroot pomaces, the sources of which are high in dietary fiber, antioxidants and bioactive chemicals like beta-carotene and betalains, were utilized as sustainable substrates to develop the nutritional aspect of the crackers. Chickpea flour, being a rich source of proteins and having a positive effect in baking, was chosen. In the study, it was considered to develop healthier snacks while promoting waste valorization and nutrition health. Sensory qualities and general acceptability were assessed by panel testing. Besides, physicochemical tests, moisture content, fiber content, and antioxidant activity were also carried out. The outcome suggested that crackers prepared with optimum levels of vegetable pomace and chickpea flour contained better sensory quality and greatly enhanced nutritional qualities than the traditional crackers. This research emphasizes the viability of using vegetable by-products in mainstream foods as a health-focused snacking option.

INTRODUCTION

Vegetables among the most important grubs and completely healthy as they are rich in vitamins, minerals, fiber, and antioxidants but have low calorie content. Their dietary features include a high content of Vitamin A, Vitamin C, Vitamin K, several B complex vitamins, and some potent minerals like potassium, magnesium, and calcium. Fiber in the diet has been found to lower the risk for other chronic diseases, particularly heart disease and some cancers (Slavin, 2013). A good proportion of vegetables incorporate some active oxidation- killing agents that help fight oxidative maladies in the body, which decreases inflammatory and chronic disease chances of the body (Boeing et al., 2012). Carrots (*Daucus carota)* belong to this group of crops since they also provide good vitamins that contain potassium and vitamins A, C, and K. Carrots are found to be beneficial to eye health and also lower the risk of cardiovascular diseases (Char, 2017). There is the waste consisting of peels and skins that are mostly taken off in the processing of food, for example, oranges and bell peppers, and there are the tops and leaves that people have a tendency to throw away even though these are edible and very nutritious. Such greens can be added to salads, or served with the vegetables as subsidiary food. It is practiced that carrot and beetroot waste can be composted so that nutrients are returned to the soil and thus build the soil. Also, these waste components can be incorporated into animal feeds and reduce waste while feeding animals healthy (Mourad et al., 2021). Chickpeas *(Cicer arietinum),* popularly known as garbanzo or Indian pea, were cultivated since ancient times and are one of the leguminous plants that are constantly used in cuisine all over the world. Most cultures prized these legumes because of their ability to be used in many ways when cooking and due to health benefits-worth nutrients locked in thereof. Vegetarians and vegans often choose them because they are a great source of plant-based protein. A cup of cooked chickpeas contains around 15 grammes of protein, an essential nutrient for muscle growth and repair (USDA, 2019). Besides protein, chickpeas contain other components, such as dietary fiber, which can help in digestion and in the control of blood sugar levels. This high fiber content may also cause satiety, therefore helping those individuals who are on weight loss programs to include chickpeas in their meals. In addition, they are known to have vitamins and minerals such as folate, iron, magnesium, and potassium. Folic acid is especially vital in cell reproduction, and therefore pregnant women take it to help in the growth of their babies (Bhat et al. 2018). Chickpeas supply antioxidants, which aid against oxidative stress in the body. There are a number of sundry phytochemicals, including active components such as saponins and flavonoids, which aid nut rophication and have been associated with a low incidence of heart diseases and certain cancers (Nadeem et al. 2020). The consumption of chickpeas on a regular basis is likely to be beneficial in the management of heart diseases secondary to reductions in cholesterol levels and blood pressure. In the same way, chickpeas also have a relatively low glycaemic index, meaning those who are diabetic can eat them. The stabilization of the blood sugar levels can be explained by the fact that the carbohydrates are digested and absorbed at a slower rate due to the high amount of fiber and protein content (Shafique et al. 2018). The chickpeas could be included in the preparation of salads, soups, casseroles, and even curries. When grounded to flour, they can also be used in baking. This versatility of chickpeas makes them well-liked in many ethnic cuisines, as they soak up flavors very well. Besides the health benefits, chickpeas are also very beneficial to the environment. They can improve nitrogen levels in the soil because they are a nitrogen-fixing crop, thereby decreasing the use of chemical nitrogen fertilizers. This makes them an agricultural economic alternative and an important aspect of crop rotation systems (Khan et al., 2021). vegetable pomace crackers are a nutritious and creative snack prepared from the waste product. These crackers make use of the spent pomace, which is fibrous and contains vitamins and minerals, most of which is normally discarded during the juicing of carrots, vegetables, and greens. By making use of this pomace and making it into biscuits, food spoiling is avoided and the general public is offered a healthy and very delicious biscuit to eat (Bauer et al., 2019). Depending on the vegetables used, crackers can provide a good source of potassium, magnesium, and other vital minerals (Nadeem et al., 2021). The vegetable pomace crackers offered are largely adaptable, and even different herbs, spices, and seeds can be added to the mixtures so as to improve their flavor. They provide a spreadable surface area for spreads like hummus, guacamole, or nut butter, while also being consumed as a crunchy snack. Their attractive nature, thanks to their texture and flavor, also targets the health conscious as well as the innovators on the snack market (Jiang et al., 2022). Use of vegetable pomace crackers' is associated with one major advantage, which is the reduction of food waste. These snacks are eco-friendly because they use waste materials that could have been thrown away. This is consistent with the emerging trend of using food waste and supports the aim of a circular food system (Khan et al., 2021).

MATERIALS AND METHODOLOGY

The research will occur in the Human Nutrition and Dietetics department of Riphah International University Faisalabad. This study targets to examine both the nutritional properties and antioxidant features of crackers made with combination of chickpea flour and carrot and beetroot pomace residues. The main purpose is to create functional food products from industrial waste vegetable pomace which give additional value through enhanced dietary fiber consumption and antioxidant benefits.

Treatment plans

Treatment	Chickpea flour %	Pomace %
T_0	100	0
T_1	90	10
T_2	80	20
T_3	70	30
T_4	60	40
T_5	50	50

The preparation of crackers starts with Kuchtová et al. (2016) method that has been adjusted to blend vegetable pomace with chickpea flour. The recipe involves mixing chickpea flour with salt, carrot and beetroot pomace (for fiber and antioxidants), and a teaspoon of olive oil. Water is gradually added to form a smooth dough, which is rolled between parchment sheets to 1/8-inch thickness, cut into cracker shapes, and baked at 350°F (175°C) for 15–20 minutes until golden and crispy.

A standard analysis of raw ingredient proximate composition following AOAC (2016) procedures will be conducted on carrot pomace and beetroot pomace together with chickpea flour.

In order to measure total polyphenols the Folin-Ciocalteu technique was employed. Thanks to an increase in the quantity of aromatic phenolic, which raises absorption, the phosphotungstic acid in the technique described is converted to phosphotungstic acid blue. 50μL of extract, 250μL of Folin-Ciocalteu regent, and 750μL of sodium bicarbonate were added to the test tubes for this purpose. A final volume was then created using 5mL of distilled water, and the test tubes were covered with aluminum foil and left in a dark area for about two hours. The absorbance was determined using a spectrophotometer set at 765 nm, after the designated time, and compared to a control sample that contained all reaction reagents except for the sample aqueous extract (Cosmulescu & Trandafir, 2012).

Samples were examined for DPPH. Each test tube received 3 milliliters of freshly dissolved 1 milligram DPPH mixed in 100 milliliters of methanol after the sample extracts (0.0256 milliliters) were combined with 10 milliliters of ethanol. The samples that were ready were left in the dark for fifteen minutes. The UV visible spectrophotometer was used to quantify the absorbance at 517 nm. The very stable and oxidizing radical DPPH created a yellow-colored hydrazine throughout the entire process, which is also connected to the elimination of free radicals with the hydrogen atom of the phenolic molecule (Braca et al., 2002).

The sensory evaluation of the crackers rated with a hedonic scale of 9 points as described in Akonor et al. (2016). The assessment of the product for sensory quality will rely on 10 to 15 trained panelists operating in controlled laboratory settings. Panels must rinse their mouths with water between each taste assessment to prevent taste interferences.

The Statistical Package for the Social Sciences software will analyze all data obtained from analytical and sensory tests. The study employs ANOVA tests to establish any statistically important dissimilarities which appear between different formulations. The study will use Montgomery (2017) guidelines to deliver precise results interpretation.

RESULTS AND DISCUSSION

Obesity, Cardiovascular diseases and Type 2 diabetes are some examples which are increasingly being attributed to unhealthy calorie-dense snack consumption. Functional food products, with acute need of offering functional attributes towards supporting health maintenance promotion as well prevention and sustainability i.e. meeting nutritional requirement are becoming more in demand. To make crackers by chickpea flour and vegetable pomace can be a good way in the current trend. The crackers designed are high in dietary fiber, plant based protein and essential vitamins, minerals like potassium, magnesium, iron and folate. Moreover, the incorporation of pomace such as beetroot and carrot makes the product more nutritionally sound with no increase on cost. These are healthier snack options because they contain next to no saturated fats and added sugars.

Table 1

Compositional Analysis of Raw Ingredients (Mean ± S.D)

Parameter	Chickpea Flour	Carrot Pomace	Beetroot Pomace
Moisture (%)	10.24 ± 0.3	8.37 ± 0.5	9.85 ± 0.4
Ash (%)	2.84 ± 0.2	5.12 ± 0.4	6.03 ± 0.3
Crude Protein (%)	20.87 ± 0.2	6.42 ± 0.3	7.95 ± 0.4
Crude Fiber (%)	10.26 ± 0.4	17.88 ± 0.3	18.43 ± 0.5
Crude Fat (%)	6.42 ± 0.3	2.16 ± 0.2	1.83 ± 0.2
NFE (%)	60.31 ± 0.4	59.45 ± 0.5	61.96 ± 0.6

The moisture content of the tested raw materials was found to be 10.24±0.3% in chickpea flour, 8.37±0.5% in carrot pomace, and 9.85±0.4% in beetroot pomace. Moisture content plays a significant role in determining the shelf life, microbial stability, and textural quality of food products. The relatively lower moisture content in carrot and beetroot pomace is beneficial for improving the storage stability of the final crackers. These values are consistent with the findings of Haug et al. (2013), who reported moisture values in carrot pomace ranging from 8–10%, and Gopal et al. (2015), who observed similar moisture levels in beetroot pomace. In comparison, the moisture content of chickpea flour aligns with the values reported by USDA (2019), where chickpea flour showed typical moisture content between 9.5% and 11%, supporting its suitability for dry baked products like crackers.

Ash content is indicative of the total mineral content present in a food ingredient. The ash values recorded were 2.84±0.2% for chickpea flour, 5.12±0.4% for carrot pomace, and 6.03±0.3% for beetroot pomace. The higher ash content in vegetable pomace reflects the presence of essential minerals such as potassium, magnesium, and calcium, which are beneficial for human health. The results are in accordance with previous findings by Chung et al. (2017), who reported ash content in carrot pomace ranging from 4.8% to 5.3%, and Gopal et al. (2015), who documented similar values in beetroot pomace due to its rich mineral profile. Chickpea flour's ash content corresponds with standard ranges reported by Bhat et al. (2014).

Protein is a vital macronutrient necessary for growth, tissue repair, and enzymatic functions. The crude protein content of the raw materials was found to be 20.87±0.2% in chickpea flour, 6.42±0.3% in carrot pomace, and 7.95±0.4% in beetroot pomace. Among these, chickpea flour showed the highest protein content, making it a valuable base ingredient for enhancing the protein quality of the developed crackers. The results are consistent with USDA (2019) reports, which cite chickpea flour protein content in the range of 20–22%. The moderate protein content in beetroot and carrot pomace is in agreement with values reported by Gopal et al. (2015) and Chung et al. (2017), respectively, where vegetable pomaces still retained reasonable protein levels post-juice extraction.

Crude fiber plays a crucial role in promoting digestive health, maintaining blood sugar levels, and aiding in cholesterol management. The crude fiber content was recorded as 10.26±0.4% in chickpea flour, 17.88±0.3% in carrot pomace, and 18.43±0.5% in beetroot pomace. The results indicate that vegetable pomaces, particularly beetroot and carrot, are excellent sources of dietary fiber. These findings support previous studies by Haug et al. (2013), which reported carrot pomace fiber content ranging from 17–20%, and Gopal et al. (2015), who documented similar values for beetroot pomace. Chickpea flour also contributed significantly to total fiber, aligning with values reported by Bhat et al. (2014), confirming its role as a nutritionally functional grain legume.

Crude fat refers to the total lipid content in food materials and is important for providing essential fatty acids and aiding in the absorption of fat-soluble vitamins. The crude fat content in the raw materials was observed to be 6.42±0.3% in chickpea flour, 2.16±0.2% in carrot pomace, and 1.83±0.2% in beetroot pomace. Chickpea flour contributed the most fat content, consistent with USDA (2019), which reports fat in chickpeas ranging from 6–7%. The low-fat levels in carrot and beetroot pomace are beneficial for the development of low-fat functional snacks, especially for consumers managing cardiovascular risk. These values are also comparable with results reported by Gopal et al. (2015) and Chung et al. (2017), where carrot and beetroot pomace retained minimal fat post-juice extraction, supporting their use in calorie-controlled formulations.

NFE values were 60.31±0.4% for chickpea flour, 59.45±0.5% for carrot pomace, and 61.96±0.6% for beetroot pomace. These results indicate that all three ingredients are rich in digestible carbohydrates, especially chickpea flour, which contributes to the energy content of the developed crackers. These findings are supported by Parker et al. (2012), who emphasized the carbohydrate richness of chickpeas, and Gopal et al. (2015), who noted substantial residual carbohydrate content in pomace materials, making them suitable for energy-dense, fiber-rich snacks.

Table 2

Effects of Storage and Treatment on TPC ± S.D (mg GAE/100g)

Treatment	0 Days	15 Days	30 Days	Mean ± S.D
T 0	84.02±4.17	81.82±4.16	74.80±4.14	83.22±4.15
T1	605±5.50	603±5.20	605±4.90	605.33±5.20
T2	101.79±3.67	101±3.63	99.70±3.61	100±3.66
T3	39.20±0.90	28.85±0.70	28.80±0.60	28.29±0.73
T4	90.21±45	88.20±44	88.15±43	88.52±44.00
T5	77.52±0.22	76.41±0.20	75.29±0.20	76.39±0.35

The results of total phenolic content (TPC) of crackers prepared from different combinations of chickpea flour and vegetable pomace were observed and recorded over 30 days of storage. The mean values of TPC were recorded as follows: T0 = 80.22±4.15, T1 = 606.33±5.20, T2 = 100.50±3.66, T3 = 29.28±0.73, and T4 = 888.52±44.00 mg GAE/100g. The control group T0, prepared using 100% chickpea flour, showed a gradual decrease in TPC from 83.02 to 76.80 mg GAE/100g during 30 days of storage. Similarly, T2 (80% chickpea flour + 20% pomace) showed a slight decrease in TPC from 102.79 to 98.70 mg GAE/100g. Treatment T3 (70% chickpea flour + 30% pomace) showed a notable reduction from 30.20 to 27.80 mg GAE/100g. In contrast, T1 (90% chickpea flour + 10% pomace) maintained a relatively stable TPC around 606 mg GAE/100g throughout the storage period. Most significantly, T4 (60% chickpea flour + 40% pomace) exhibited the highest antioxidant activity, with only a slight drop from 900.21 to 885.15 mg GAE/100g, making it the most effective treatment in retaining phenolic compounds during storage. The results of this study suggest that higher inclusion of vegetable pomace, particularly at 40% (T4), contributes significantly to enhanced antioxidant properties. Treatment T1 and T2 also showed promising TPC levels, while T3's low and declining values indicate it may be less suitable for preserving antioxidant compounds. The results of this examine recommend that higher inclusion of vegetable pomace, especially at 40% (T4), contributes drastically to superior antioxidant properties. treatment T1 and T2 additionally showed promising TPC levels, even as T3's low and declining values imply it may be less appropriate for maintaining antioxidant compounds (Shrestha, 2022).

Table 3

Effects of Storage and Treatment on DPPH ± S.D (%) of Vegetable Pomace and Chickpea Crackers

Treatment	0 Days	15 Days	30 Days	Mean ± S.D
T0	25.20±0.40	24.98±0.30	24.70±0.20	24.90±0.30
T1	55.90±0.80	54.80±0.70	53.07±0.60	54.59±0.70
T2	32.83±0.50	28.80±0.60	31.70±0.30	31.11±0.47
T3	75.50±0.20	74.40±0.40	75.30±0.50	74.40±0.36
T4	54.50±0.80	53.40±0.80	55.20±0.10	55.36±0.57
T5	63.21±0.60	64.23±0.70	63.21±0.90	61.55±0.73

In antioxidant activity of vegetable pomace and chickpea flour based crackers, antioxidant potential was determined through DPPH free radical-scavenging ability. The analytical method was evaluated over 0 (control treatment) to 15 and 30 days treated samples and observed the effects of various treatments on antioxidant capacity. The recorded DPPH values ranged from 24.70% to 76.50%. Treatment T3 (70% chickpea flour + 30% vegetable pomace) showed the highest DPPH values consistently across all storage days, from 76.50% at day 0 to 74.30% at day 30. This indicates a high retention of antioxidant activity, making it the most effective treatment among all. Treatment T5 (60% chickpea flour + 40% pomace) also demonstrated stable antioxidant potential, increasing slightly from 61.21% at day 0 to 62.23% at day 15, and then maintaining 61.21% at day 30. On the other hand T0 possessed the most DPPH activity, and it decreased gradually from 25.20% to 24. 70%, in increasing levels of treatments. Lower and for the pomace fractions(T1 :10 % and T2 :20 %), antioie radical activity showed general reduction but higher than the control (Treatments based on ploemace). This study was confirmed by Bialek et al. (2015) they found that the DPPH activity for pumpkin seed flour ranged between0and64%, the same order of magnitude can be seen in T3 or T5.values. Thus, the findings indicate that crackers enriched with 30% or more vegetable pomace (especially T3 and T5) retain higher antioxidant activity and could serve as promising functional snacks for health-conscious consumers.

Table 4

Effects of Storage and Treatment on Texture ± S.D of Vegetable Pomace and Chickpea Crackers

Treatment	0 Days	15 Days	30 Days	Mean ± S.D
T0	7.05±0.12	7.03±0.15	7.02±0.18	7.33±0.15
T1	7.04±0.11	7.02±0.14	7.01±0.15	7.23±0.13
T2	7.00±0.01	6.98±0.09	6.95±0.08	6.97±0.06
T3	6.96±0.07	6.95±0.06	6.94±0.05	6.95±0.06
T4	6.93±0.08	6.97±0.05	6.93±0.07	6.94±0.06
T5	6.05±0.06	6.45±0.08	6.35±0.03	6.43±0.05

The texture of crackers prepared with chickpea flour and vegetable pomace (carrot and beetroot) was evaluated through sensory analysis over a 30-day storage period. The control treatment T0 (100% chickpea flour) showed the highest texture score with a mean of 7.33 ± 0.15, followed by T1 (90% chickpea + 10% pomace) with 7.23 ± 0.13. The lowest score was observed in T5 (60% chickpea flour + 40% pomace), which had a mean score of 6.43 ± 0.05. It was observed that texture scores generally declined slightly during storage across all treatments. For instance, T0 decreased from 7.05 at day 0 to 7.02 at day 30, while T5 showed a greater drop from 6.45 at day 15 to 6.35 at day 30. Although the variation is minimal, it indicates that higher levels of pomace may slightly reduce the crispness and firmness of the crackers over time. On the other hand, studies such as Bello et al. (2020) demonstrated that cookies made with composite flours such as unripe plantain and watermelon seed showed no significant difference in texture when compared to standard wheat cookies, especially at lower substitution levels. Overall, the texture of vegetable pomace and chickpea flour crackers remained acceptable up to 30 days, especially in treatments T0 to T2. Treatments with higher pomace ratios (T4 and T5) showed slightly reduced textural appeal, but still remained within acceptable sensory limits.

Table 5

Effects of Storage and Treatment on Taste ± S.D of Vegetable Pomace and Chickpea Crackers

Treatment	0 Days	15 Days	30 Days	Mean ± S.D
T0	7.20±0.20	7.50±0.30	7.60±0.40	7.43±0.30 ab
T1	7.90±0.70	7.80±0.50	7.50±0.50	7.73±0.50 a
T2	7.50±0.40	7.30±0.20	7.20±0.30	7.33±0.30 a
T3	7.30±0.40	7.20±0.20	7.10±0.30	7.20±0.30 ab
T4	7.10±0.50	6.90±0.70	6.90±0.40	7.00±0.50 b
T5	6.90±0.50	6.90±0.10	6.90±0.20	6.95±0.20 b

The sensory evaluation of taste for vegetable pomace and chickpea flour-based crackers was conducted over a 30-day storage period. Treatment T1 (90% chickpea flour + 10% vegetable pomace) received the highest average taste score of 7.73 ± 0.5, indicating the most favorable taste perception among panelists. In contrast, T5 (60% chickpea flour + 40% pomace) had the lowest score of 6.95 ± 0.2, suggesting that higher pomace levels may slightly reduce taste acceptability. These results align with findings from Fabil et al. (2024), who noted that incorporating jackfruit seed flour into wheat biscuits enhanced taste up to a certain limit (20%), beyond which bitterness was introduced. Similarly, Fontana et al. (2024) observed that cookies with higher levels of grape pomace flour scored poorly for taste due to bitterness and lack of crispness, despite their nutritional benefits. Treatments T1 and T2, with moderate levels of pomace, showed the best balance of taste and health attributes, making them more suitable for product development. In contrast, T4 and T5 with higher pomace content may benefit from formulation refinement to improve palatability.

Table 6

Effects of Storage and Treatment on Overall Acceptability ± S.D of Vegetable Pomace and Chickpea Crackers

Treatment	0 Days	15 Days	30 Days	Mean ± S.D
T0	8.0±0.3	7.95±0.3	7.8±0.2	7.91±0.2^{a}
T1	7.7±0.6	7.65±0.4	7.6±0.2	7.65±0.4^{ab}
T2	7.55±0.7	7.50±0.5	7.45±0.3	7.50±0.5^{ab}
T3	7.4±0.8	7.35±0.6	7.3±0.4	7.35±0.6^{ab}
T4	7.25±0.2	7.20±0.4	7.15±0.3	7.25±0.3^{b}
T5	7.15±0.4	7.10±0.2	7.5±0.6	7.20±0.4^{b}

The overall acceptability of crackers made from chickpea flour and vegetable pomace was assessed through sensory evaluation during a 30-day storage period. Among all treatments, T0 (100% chickpea flour) achieved the highest score (7.91 ± 0.2), followed closely by T1 (7.65 ± 0.4) and T2 (7.50 ± 0.5). The lowest overall acceptability score was observed in T5 (60% chickpea flour + 40% pomace), with a mean value of 7.20 ± 0.4. These findings are supported by Pusty et al. (2022), who reported that cookies substituted with nutrient-rich flours had overall acceptability scores above 6 on a 9-point hedonic scale. Similarly, Bilal et al. (2020) found that cookies supplemented with peanut seed oil at 15% were most acceptable in terms of sensory and stability parameters, reinforcing that optimal substitution levels result in the best consumer acceptance. In this study, T1 and T2, which contained 10–20% vegetable pomace, showed an effective balance of nutritional enrichment and palatability, making them suitable candidates for commercial functional snack development. On the other hand, T5, which had the highest level of pomace, scored lowest, suggesting that excessive pomace addition might negatively impact sensory quality, especially taste and appearance.

CONCLUSION

This study demonstrated the development of functional foods and beverages with strong nutritional, sensory and sustainability benefits. A beetroot–lemon balm–stevia blend proved to be a potent antioxidant beverage, effectively managing oxidative stress and supporting the prevention of chronic lifestyle-related diseases. Stevia, used as a natural sweetener, improved antioxidant stability and phenolic retention without compromising sensory quality; the optimal formulation (65% beetroot, 30% lemon balm, 5% stevia) showed the highest activity and good storage stability. Sensory evaluations confirmed that stevia-containing beverages maintained favorable taste and acceptability, highlighting their potential as sugar-free, health promoting alternatives to commercial drinks. In parallel, crackers enriched with vegetable pomace and chickpea flour were well-accepted, offering enhanced protein, fiber and gluten-free potential while utilizing agro-industrial by-products. This approach reduces food waste, supports the UN Sustainable Development Goals and responds to consumer demand for eco-friendly, clean-label products. Such functional foods not only promote digestive and metabolic health but also provide commercially viable options for sustainable product innovation.

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