



PROTEIN (SOYA FLOUR) DEVELOPMENT OF HIGH-PROTEIN KHAKHRA USING DAIRY BY-PRODUCT (WHEY WATER) AND PLANT

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ABSTRACT

Developing interest in highly nutritious and easy-to-consume convenient food has driven traditional food processing methods into value addition in processing it with nutritionally rich materials. Khakhra, a traditional very thin, crispy & ready to eat snack mostly consumed in western & north western part of the country and having wide scope for nutritional alteration owing to its unique features viz. Easy to eat form & easy-to-keep characteristics along with many others compared to flour used in its composition. Different materials viz. Sesames seed flour, curry leaf powder, garden cress seed, buckwheat, pumpkin powder, red rice, flaxseed were earlier incorporated to the khakhra and various nutritive properties got improved while keeping up the acceptable quality of the product. A plant source- protein rich ingredient like soy flour may be good substitute when to use with cereal based foods. From studies made on enriched with soy flour fritters, the protein, crude fiber, ash, fat and amylose content significantly enhanced by soy incorporation, however color, appearance, texture etc., changes may depends on level of soy incorporation into food . Whey is a nutritiously acceptable product of dairy by-product (lactose protein minerals & water soluble vitamin). Composition of whey differs based on type of milk sources. Valorization of dairy whey gained importance from nutritive, technological & environmental point of view and gained importance. Nutritive value, high biological & chemical value. It also provide better functionality in terms of solubility and emulsification properties, gel formation ability etc. Hence, the addition of Whey water along with soy flour to khakhra will offer good way for combination of two protein sources together while adding value to the dairy by-product. Therefore to find out precise answer about the optimum proportion of Whey water, soya flour; and impact of addition on nutritional characteristic, consumer acceptability and shelf life there is still need for study. Hence, in this review is to throw light on khakhra based nutrient enrichment, soy flour, whey and nutritional aspects as well as various functional food & industrial opportunities available by use of soy flour & whey to make high-protein khakhra.

Key words: Khakhra, Whey water, Whey protein, Soya flour, Plant protein,

1. INTRODUCTION

Development of nutritious and easily consume foods has remained a major subject for study within food sector considering consumers' expectations to satisfy taste preferences with balanced nutritional value of foods. Snacks hold an important position on diet list of today due to their convenient and fast eating nature and can be prepared by combining various cereal grains, pulses, seed and various nutrient rich products. Due to their acceptable sensory characteristics and common acceptance amongst consumers, the nutritional profile of the ready to eat traditionally prepared snacks can be nutritionally altered.

Khakhra, the ready-to-eat snack originating mostly from western and north- western Indian parts and specifically Gujarat has emerged to be favorite in numerous households. Generally prepared from entire wheat flour & fat (oil), Khakhra can serve both as a staple in meals and snack depending on serving and preparation procedures and may be stored for long due to its crispy & baked structure. Various researchers have employed many novel approaches to supplement cereals through addition of alternate grains, seeds, vegetables and other dietary supplements or functional foods for enhancing their nutritional profile. The use of blended flours has become one of the major directions for improved khakhra preparation like addition of composite flours comprising of roasted

sesame seed flour, curry leaf powder at suitable proportion exhibited good improved nutritional value and acceptable quality traits of prepared Khakhra (Kajla *et al.*, 2020). Solanke *et al.* (2020),

When developed charkha incorporated with a mixture of garden cress seed flour & buck wheat flour at different inclusion levels, it enhanced various nutritive values viz Protein, Fat, Iron etc as they increased with composite flour concentration. Further study aimed at assessing the feasibility of using red rice, buckwheat and flaxseed for preparation of khakhra have shown good impact on nutritional parameters namely Minerals, Protein, dietary fibers. The aforementioned study has proved that the traditional savory food Khakhra can be effectively used for nutritionally modifying food matrices but none of the earlier stated researches dealt with use of combination of dairy by-product & nutrient rich plant source of protein as well as limited information is available on how we combine both to obtain high nutrient density savory food item, which we will learn in subsequent section. (Bartwal *et al.*, 2020; Patel & Singh *et al.*, (2023).

A plant sources- protein rich source like Soya flour have proven to give rise to nutritious products due to protein source with essential amino acid profile when blend with cereals to improve the nutrition value of food. It is beneficial to mention that it has used soy protein enriched Fritters at various inclusion rates which improved its Protein, crude Fiber, ash, fat and amylose values of fritter significantly though, Color, appearance, texture vary. Whey- a nutritious dairy by-product is made up from proteins, lactose, minerals & soluble vitamins. Alamu *et al.* (2018) Chemical contents of the whey varies dependent on source and composition. Utilization of this cheap dairy byproduct has gained importance, nutrition technology and environmental impact considered (Mirzakulova *et al.*, 2025).

Whey proteins have also been studied due to its nutritional and functional properties. De Wit (1998) proposed that whey proteins are high-value foods having a range of functional properties and an extensive number of applications in various food systems. More recently a focus has been applied to turning the undervalued food waste into high-value food ingredients, not just for its functionality but also in order to tackle the disposal burden that whey causes and .The introduction of soya flour along with whey water in khakhra is thus of great interest in enriching the product's nutritive value as well as utilizing the whey by-product. The concept could yield a product combining both the plant protein source together with the dairy based ingredients and preserving the existing characteristics of khakhra. Despite this, it is imperative to know how both whey water and soya flour would affect the Dough texture and nutritional contents, sensory properties and storage ability of khakhra in a scientifically proper manner. (Mirzakulova *et al.*, 2025).

2. KHA KHRA AS TRADITIONAL FUNCTIONAL SNACK

Khakhra is an Indian thin, crisp traditional Indian snack that is very popular across many ages due to its ready to eat characteristics and convenience to consumption and portability in form of a snack. It is composed of few basic flours that make it suitable and appropriate to introduce alternative flours and nutritive ingredients. khakhra is a convenient food that is ready to be consumed at its ready state without further processing and has a long shelf-life span. structure wise a khakhra can be categorized as a food that has huge potential for functional fortification. Proteins, fiber and mineral contents can be drastically altered depending on the flour compositions that are introduced. The color, flavor texture and crispness of khakhra is expected to be altered by this change in its nutritional profiles. Hence there have been studies done on various flour compositions, in an attempt to achieve the optimum for acceptable nutritional benefits and desirable sensory attributes (Kajla *et al.*, 2020; Solanke *et al.*, 2020).

Composite flours containing oat flour, roasted sesame seed flour and curry leaf powder have been investigated in regard to preparation of khakhra .This revealed the benefits in adopting inclusion of nutritive elements in khakhra without reducing its consumer acceptability values. This supports the hypothesis that seeds and leaf ingredients could play a significant role in elevating the nutrition level of conventional snack product.(Kajla *et al.*, 2020)

Garden cress seed and Buckwheat flour was also subjected to studies on incorporation into khakhra where both the ingredients have been added in certain levels, which resulted to enhanced nutrient values of fat, protein and iron in direct proportion to its inclusion levels and analysis performed has showed consistent improvement in nutrients along with sensory properties Solanke *et al.* (2020). The researchers have made investigation over 3 month period on interval of 30 day in terms of all the quality parameters mentioned above of such studied khakhra at room temperature which explains the essence and importance of monitorization of quality and nutrients on regular interval. So the work performed before in various other forms support that khakhra could be functionalized food. The proposal here would enable not only fortification in the way plant protein content could be raised but also an attempt to utilize dairy by-product in form of whey water with the addition of soya flour with other potential health beneficial ingredients. Solanke *et al.*, (2020).

3. PREVIOUS APPROACHES TO NUTRITIONAL FORTIFICATION OF KHA KHRA.

3.1. Sesame Seed and Curry Leaf

Fortification: Both roasted sesame seed flour and curry leaf powder added to a composite flour to make khakhra. They aim was to incorporate nutrient quality, without sacrificing sensory characteristics, into khakhra. Both curry leaf powder and sesame seed flour are nutritionally dense seeds that could provide enhanced fibre and protein content. They also have antioxidant and anti-inflammatory benefits. This relevant because it showed how khakhra's might become nutritious without necessarily destroying the product, supporting the idea of composite flour formulations for healthy foods. Kajla *et al.* (2020)

3.2. Garden Cress Seed and Buckwheat Fortification:

The nutritional impact of garden cress seed and buckwheat flour were tested and incorporated into a composite khakhra product. This was compared that the product to pure whole wheat khakhra by using different percentages of garden cress and buckwheat flours to substitute from pure whole wheat flour. The research revealed that by incorporating the two new ingredients the overall nutritional value increased, notably in terms of the total fat content, protein and the mineral content (iron). Another aspect of their

research focused on the three-month storability and evaluated storage over time by assessing and comparing a number of physiochemical traits of the khakhra. Solanke *et al.* (2020).

3.3. Red Rice, Buckwheat and Flaxseed:

Red rice, buckwheat and flaxseed used to make the multigrain form of khakhra. This contains plenty of fibre, carbohydrates, proteins and important minerals. However the emphasis of this study was placed on the potential for multigrain diets with different sources of carbohydrate and protein, for example they indicated that this would reduce reliance on wheat. In contrast this study focuses solely on the impact of soya flour and whey water on the protein quality. Bartwal *et al.*, (2020)

3.4. Pumpkin powder fortification:

The incorporated unripened pumpkin powder with oats, maize and wheat flours, resulting in a unique and nutritious khakhra product, that was analyzed for its physico – chemical parameters and stability through various storage conditions, this contained nutrient information such as protein, fibre, carbohydrates, iron etc. The developed khakhra was then stored for three months in refrigeration and ambient conditions. This indicates that when formulating added value traditional products, both nutritional assessment as well as product storage has to be conducted. Together, the studies reveal that khakhra can be effectively formulated using seeds, pseudo cereals, vegetables, composites cereal flours, but Limited literature is available on using a combination of whey water and soya flour amongst the reference document reviewed. Patel and Singh *et al.*, (2023)

4. SOYA FLOUR AS A PLANT PROTEIN SOURCE

Soybean is an important plant source, of protein and is being explored to fortify the dietary value of cereal-based products. Incorporating soya flour can add not only to the protein content but also some other Nutritional constituents, making it a suitable ingredient in the formulation of protein rich foods.) The study on the effect of soya flour on the nutritional property and consumer preference on the fritters. The formulation of unfortified and soya-fortified product resulted in the significantly higher ash, fat, amylose, crude fiber and protein contents of the soya-fortified product, a 55.5 % improvement of the product being noticed compared to the unfortified one. Alamuet *et al.*, (2018)

Using the same method of structured sensory analysis a total of 291 participants were engaged and tasted the product, scoring its colour, appearance, aroma, texture and taste on a 7-point hedonic scale. Also intent to use and Willingness to pay were evaluated. Importantly, for the present purpose soya ingredient at any level did not bring statistically significant difference in overall preference, as well as for taste and texture, although some testers reported preference for the soya fortified fritter. However, it is necessary to mention that the physical attributes of cereal-based food products may be affected by the soya ingredients incorporation, namely an increase in firmness and density due to possible interactions of soya ingredients with the gluten matrix, due to water uptake by the fibre component of the flour as well as to increase in dough viscosity.

Proteins present in soya flour may contribute also to texture realization under heat. These are of particular relevance to khakhra, in which crispness and texture are quality determining factors; Therefore, when planning soya inclusion for better protein value it is necessary to optimize its amount to get appropriate texture, correct dough working as well as roasting Mirzakulova *et al.* (2025)

This state that the liquid whey is typically composed of about 93–95% water, and in the dry matter, there are lactose, whey proteins, minerals, lipid and other constituents. Also, the authors point out that the constitution of whey differs between sweet, acid or other types of whey according to the production method. The nutritional merit of whey is related to its soluble milk constituents. The review under consideration, in turn, states that whey is composed of proteins, lactose, mineral salts and water-soluble vitamins, and that the protein part of whey has a good distribution of amino acids. Due to a much lower protein content in liquid whey as compared to concentrated whey protein ingredients, it should be differentiated between whey water/liquid whey and whey protein concentrate or isolate when using them for food formulation. From the given material, it is possible to conclude that in case of sweet whey, protein content is about 0.8–1.0%, while in case of concentrated whey ingredients – very higher amount of proteins.

In view of the latter assumption, a differentiation will be necessary with regard to the designed khakhra, because the use of whey water will not be necessarily accompanied with similar nutritional effect to adding of Whey Protein Concentrate (WPC) or Whey Protein Isolate (WPI). The real contribution of the protein whey water must be measured experimentally for a specific dairy product which will be used for making.

5. NUTRITIONAL AND FUNCTIONAL PROPERTIES OF WHEY PROTEINS

whey proteins as food ingredients are well understood as nutritionally superior and versatile functional ingredients in foods. According to de Wit (1998) whey protein Have a high nutritional value and are very versatile in use in food products.. Major whey proteins include; -lactoglobulin, -lactalbumin, bovine serum albumin and immunoglobulins along with small amounts of bioactive species such as lactoferrin and lactoperoxidase (de Wit, 1998).

The properties are related to the molecular structure of the proteins (de Wit, 1998). Whey proteins have been successfully applied in numerous food systems based on functionality, for example dairy-, confectionery- and bakery products, and functionality, and nutritional contributions have been of interest (de Wit, 1998). Mirzakulova *et al.*, (2025),

A recent review, confirms the functionality as important functional property for whey proteingelation, emulsification, and foaming in functional food and beverages. It should be noticed, however, that results from concentrated whey protein systems can not directly be assumed, if applied on whey water, since whey water contains only a very low protein concentration; the functionality observed on a model product therefore does not automatically predicts the behaviour in a complex food system (de Wit, 1998).

This study is aimed at comparing protein yield from dairy and food ingredients for, the khakhra dough and the khakhra and to investigate the effect of whey water on khakhra dough and khakhra.

6. WHEY WATER AND SUSTAINABLE FOOD PRODUCT DEVELOPMENT

Utilization of by-products of the dairy and food processing sector is an important pillar of sustainability within the food sector. High quantities of whey arise from dairy processing. Untreated whey is rich in organic matter and can cause an environmental burden if improperly handled

Modern food-processing techniques regard whey as something much more than an environmentally harmful by-product, allowing production of food ingredients, a source of lactose and other compounds. In this way, its disposal can be minimized and value can be added (Mirzakulova *et al.*, 2025).

This circular approach to waste utilization, as observed in the supplied review, allows not only reduction in the production of a waste material but can result in more profit for the dairy industries by utilizing the whey for the production of food ingredients, beverages and other product items.

The development of value-added products from dairy by-products using ingredients such as whey will create new economic benefits and can be a potential part of the utilization of milk processing, also to make new food products. Therefore, integrating of whey in traditional food products such as khakhra can serve its dual purpose: enhancing nutrients as well as utilization of the dairy product.

8. POTENTIAL OF COMBINING SOYA FLOUR AND WHEY WATER

Combining plant and dairy protein sources is a well established approach to prepare novel nutritionally-enriched food product. It is noteworthy that in the supplied literature related to whey, it has also been reported that whey is in increasing demand and is successfully integrated to the food derived from plant sources to achieve a complementary protein profile. For the protein enrichment Soya flour is rich in the plant protein. Whey water may offer a complement of soluble dairy constituents including Lactose, Minerals, and Whey Protein.

In order to determine the real nutritive value, the actual composition of whey water that will be used will need to be analyzed, as this will be largely dependent on whey concentration and characteristics. Hence, the incorporation of this mixture might help create complementary profile; but the idea that the nutritional value would be enhanced Automatically will remain a research hypothesis unless a nutritional assay and amino profile of the blend is obtained. From the technological point of view, the soya flours may have an impact on the viscosity, texture, firmness, and water absorption properties of the dough.

On the other hand, processing will influence the functionality of Whey constituents on the food matrix. Alamu *et al.* (2018) state that the inclusion of soya flours changes various rheological and textural properties of cereal-based dough. De Wit (1998) also emphasize that protein functionality is a function of processing conditions and food matrix and so optimum level of either ingredients will be necessary to maintain the taste and acceptable texture of food product .

Too much Soya flours in the blend would alter colour, flavor & texture of the final product, where too much liquid whey would make the dough not firm .

Hence, optimum ratio should be assessed via experimentally formulation and sensory evaluated.

9. SENSORY ACCEPTABILITY OF PROTEIN ENRICHED KHAKHRA

Development of functionally enriched food products needs to address their sensory acceptability. Simply enriching a food with nutrients will not ensure consumer acceptability if the addition impacts color, flavor, taste or texture. From the literature on khakhra enrichment it is clear that nutrient enrichment does not necessarily impact sensorial acceptance if substitution rate is appropriate. This evaluated sensorial quality along with nutritional parameters of sesame and curry-leaf incorporated khakhra. Kajla *et al.* (2020)

Similar study was done in which dealt with enhanced value-added khakhra incorporated with garden cress seed, buckwheat flour with regard to nutritional values of product and overall acceptability of that Product, In literature pertaining to soy-fortified fritters, Alamu *et al.* (2018) did not found significant differences in taste and texture liking but noted that soybean implementation impacted the appearance and color of sample. Thus in assessing our khakhra, sensory analysis would include the acceptability based on appearance, color, aroma, taste, crispness, mouthfeel, texture, and overall acceptability. To strengthen the finding in selecting optimal formulation a standard hedonic scale with randomized sampling could be an appropriate procedure to analyze sensory attributes of khakhra.. The sensory methodology used by Alamu *et al.* (2018) involving coded and randomized sample sand hedonic scale can be used as good model. Solanke *et al.*, (2020), by Alamu *et al.*,(2018)

10. TEXTURE, CRISPNESS AND PRODUCT QUALITY

Khakhra intrinsically possesses crispness or crunchiness which are two of the most important sensory attribute. Incorporation of alternate protein sources could affect the overall dough rheological properties like water absorption, viscosity and resultant network structure after thermal process.

Soya flour has the potential to contribute to the increase in viscosity through water absorption into soy fibre and could play a role in the hardness of khakhra due to interaction of soy proteins and fibres with wheat gluten. It indicates that the concentration of soya flour should be optimized when making khakhra. High nutritional contribution and thus high protein concentration may result in an unpalatable food due to being either too hard or losing crispness.

Furthermore, whey proteins can also be denatured during heating. Wit, 1998 described the structure and thermal treatment as important parameters to determine the functionality of whey proteins in food systems. Thus further experimentation need to carried out on role of whey water and soya flour in dough handling, its rolling characteristic, its roasting time, moisture loss, final thickness, hardness and crispness.

9. NUTRITIONAL QUALITY

One of the primary aim of adding soy flour to the khakhra is to increase protein density. Support from similar studies relating to cereals based food products indicated that the showed significant increase in protein, crude fiber, ash content and fat when replacing wheat with soy flours.

Previous similar study also showed nutritional values could be increased by replacing existing flour component in khakhra. For instance, protein, fat and iron increase was observed when using high amount of garden cress seed and buckwheat flour showed that pumpkin-fortified khakhra are nutritionally rich composition including protein, fat, carbohydrates, fibers and minerals. (Solanke *et al.*, 2020). Patel and Singh *et al.*, (2023)

Whey provides amino acids, lactose, minerals and vitamins. However, it is different on the amount used depending on the whey types, their source or treatment. the major significant variations on whey components on the basis of different whey types.

Thus the nutritional evaluation of the proposed khakhra should involve moisture, protein, fat, ash, crude fibre, carbohydrate and selected minerals, with appropriate comparison against an unfortified control. Patel and Singh *et al.*, (2023)

11. STORAGE STABILITY

Storage stability is an important consideration for a dry, ready-to-eat snack such as khakhra. Moisture uptake can adversely affect crispness and sensory quality, while oxidation and other chemical changes may influence product acceptability during extended storage. It specifically evaluated the storage behaviour of fortified khakhra for three months, with chemical composition assessed at 30-day intervals. Patel and Singh (2023) also conducted three-month storage studies under refrigerated and ambient conditions for pumpkin-fortified khakhra. These studies demonstrate the importance of incorporating storage evaluation into the development of fortified khakhra. For whey-water and soya-flour khakhra, future research should investigate moisture content, crispness, sensory acceptability, rancidity indicators and microbiological quality at regular storage intervals. Packaging should also be considered because the final product is expected to have low moisture content and crispness is strongly affected by moisture migration. Solanke *et al.* (2020)

12. TECHNOLOGICAL CONSIDERATIONS IN WHEY UTILIZATION

Whey can be processed using several technologies depending on the intended application. describes ultrafiltration, nanofiltration, reverse osmosis, enzymatic hydrolysis and spray drying as important technologies for whey valorization. Ultrafiltration can concentrate whey proteins and produce whey protein concentrates and isolates, whereas reverse osmosis can reduce water content. Spray drying converts liquid whey into a stable powder with improved storage and transportation characteristics. For a traditional product such as khakhra, however, the direct use of liquid whey water may be more practical at small-scale or household level if hygienic quality and composition can be controlled. Mirzakulova *et al.* (2025)

At industrial scale, concentration or standardization may be necessary to obtain consistent nutritional and technological properties. The type of whey used must also be specified because sweet whey, acid whey and curd whey have different compositions. That the curd whey differs from other whey types in lactose and acidity, while protein and mineral levels vary according to the manufacturing process. Therefore, the proposed study should identify the exact source of whey water and determine its physicochemical characteristics before incorporation into khakhra. Mirzakulova *et al.* (2025)

13. QUALITY CONTROL OF WHEY WATER

Standardization of whey water is essential if it is to be used as an ingredient in food product development. The composition of whey can vary according to milk source, processing method, season and type of dairy product from which it is obtained (Mirzakulova *et al.*, 2025).

Dry matter, sodium chloride and lactose are mentioned in the provided literature as indicators of quality for whey. Soluble solids can be estimated by refractometry, and other parameters of whey water composition can be measured by conductometry and analytical methods. Therefore, in this case, whey water characteristics should be assessed prior to formulation of the proposed khakhra.

These characteristics, including pH, total solids, protein, lactose, ash, mineral content should assist in batch to batch reproducibility. Such standardization of whey water is crucial as changes in whey water composition will impact hydration capacity, flavor, browning tendency and characteristics of the final product.

14. RESEARCH GAP

Despite the evidence for various nutritionally valuable components in khakhra, the existing research for khakhra, based on the provided literature for the review, seems to highlight a gap for the combined application of Whey water and Soya flour. Research carried out so far on khakhra included fortification with Sesame, Curry leaf, Garden Cress Seed, Buckwheat, Red Rice and Flaxseed, Pumpkin Powder (Kajla *et al.*, 2020; Solanke *et al.*, 2020; Bartwal *et al.*, 2020; Patel & Singh, 2023). Soya flour has independently found to be of use for increasing protein and other nutrients in cereal based product (Alamu *et al.*, 2018) and Whey water, being one of the nutritious dairy byproduct, has been studied for its application (Mirzakulova *et al.*, 2025). Nevertheless, it does not cover the usage for the ideal mixture of Whey water and Soya flour, for khakhra and a clear gap for this particular combination can be established since optimal level of soya flour, the quantity and type of whey water, formulation and handling, roasting, nutritional composition, sensorial aspect, crispiness and storage of khakhra made with combination of whey water and soya flour is not investigated.

15. FUTURE PERSPECTIVES

Future studies on whey-water and soya flour khakhra, should, at first, focus on optimizing the combination of both ingredients through trials by comparing various proportions with respect to a standard khakhra. Optimized product formulation should also

involve determining adequate amounts of soya flour and whey water, as well as the level of incorporated ingredients such as to provide a good nutritional and sensory balance. Nutritional analysis may primarily focus on proximate composition including protein, fat, fibre, ash, Carbohydrates, moisture. Furthermore, due to the inherent presence of minerals such as calcium, potassium and magnesium in whey, the corresponding mineral analysis might be of significance, depending on the whey composition (Mirzakulova *et al.*, 2025).

The sensory evaluation of an article should include its appearance, color, aroma, taste, texture, crispness and an overall acceptance score. The procedure followed by Alamu *et al.* (2018) who had used coded randomized samples and hedonic scale (like scale from 1 to 5, where 1 represents disliked and 5 represents well liked) for evaluating the sample could be a benchmark for future consumer or sensory study. The storage study needs to be conducted under suitable storage condition for appropriate duration. In the case of past khakhra studies the storage periods had been for three months which shows the importance of monitoring the quality on storage (Solanke *et al.*, 2020; Patel & Singh *et al.*, (2023).

Furthermore the effect of packaging material on the moisture migration and crispness should be analyzed. Since whey has higher proportion of water and soluble components processing and drying conditions might be crucial while developing stable dry snack product. At industrial level feasibility and desirability of the utilization of whey as a food ingredient may be analyzed on the basis of availability, transportation, processing of whey as a food ingredient and shelf stability, hygienic quality of the raw ingredient and finished product, standardization and cost. Valorization of whey offers sustainable alternative toward circular food systems by transformation of a food processing waste stream into a high-value food ingredient (Mirzakulova *et al.*, 2025).

Consumer perception on such a food also needs to be addressed. Even though consumption of soybean fortified cereals have had acceptable consumer acceptance; the sensory preferences could vary with differing formulations and product types. The combined studies of nutritional analysis, sensory evaluation, physicochemical characterization, storage stability, cost analysis, and environmental assessment can be conducted to confirm and consolidate the viability of whey-water and soya-flour khakhra. Alamu *et al.*, (2018).

16. METHODOLOGY OF THE REVIEW

The current review is conducted based on the provided information for this research, focusing on existing studies regarding khakhra preparation, and its fortification; enrichment with plant protein; whey components and properties; and usage of dairy by-products for nutrition enhancement and sustainable food products.

The information presented in this review article came from a variety of scholarly articles and review papers on various aspects of khakhra development including preparation techniques, the nutritional profile of khakhra, the results of sensory evaluations and storage trials, the incorporated soya-flour, and the impact of whey on these factors. The information found was compiled based on key topics, such as Traditional khakhra features, Nutritional enhancement, Boosting with plant proteins, Whey composition, Properties of whey, Food sustainability, Sensory Quality, Storage stability, Gaps in research, and Future perspectives.

In terms of presenting the findings, emphasis is given to evidence identified from existing studies rather than empirical research results. As a result, any conclusions drawn regarding the feasibility and characteristics of the proposed whey-water and soya-flour khakhra represent a consolidation of the current evidence and highlighted opportunities for future studies.

17. CONCLUSION

The current literature suggests that incorporation of nutritionally rich components in traditional khakhra has significant potential in improving its nutritional quality. Using sesame seed and curry leaf, garden cress seed and buckwheat, red rice and flaxseed, pumpkin powder as ingredients showed that khakhra can be used as a versatile base for the nutritional fortification (Kajla *et al.*, 2020; Solanke *et al.*, 2020; Bartwal *et al.*, 2020; Patel & Singh, 2023).

Soya flour offers a very good plant-protein option as its inclusion into cereals has resulted in increased levels of protein and other nutrients. However, sensory analysis has revealed that within the established range of incorporation, consumers find these ingredients acceptable.

The quality attributes such as appearance, color and texture might be affected (Alamu *et al.*, 2018). Whey: being a dairy by-product it is rich in lactose, minerals, vitamins and proteins which are often affected by the type of dairy process. It is known that such by-products can be effectively used in circular economy framework (Mirzakulova *et al.*, 2025). Whey proteins have good nutritional value and functional attributes, the extent of which depends on many variables, including concentration, process, and interaction within the food matrix (de Wit, 1998).

From the available literature, the combination of soya flour and whey water to improve the nutritional profile of khakhra appears promising for enriching of plant protein and utilizing the by product from dairy industry. Kajla *et al.*, 2020; Solanke *et al.*, 2020; Bartwal *et al.*, 2020; Patel & Singh *et al.*, 2023)

However the effect of such a combination on the nutritional and Technological attributes of khakhra as well as sensory attributes and storage stability remains to be confirmed. Future work must focus on optimizing the formulation, standardizing the whey water composition, studying the nutritional, Sensory and storage attributes, and the impact of packaging. Cost and acceptability also needs investigation and comparison with the original Product.

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