JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

HEALTHY CHOCOLATES: A REVIEW ON FUNCTIONAL INGREDIENTS, NUTRITIONAL BENEFITS AND FORMULATION STRATEGIES

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ABSTRACT

Chocolate is enjoyed by many people, but there is growing interest in improving its nutritional value while retaining its familiar taste and texture. One approach is to explore the use of functional ingredients such as oats, flaxseed, nuts, and dietary fibre in chocolate formulations. Oats can contribute dietary fibre, flaxseed provides fibre and alpha-linolenic acid, and nuts supply unsaturated fats and other nutrients. Dietary fibre may also be incorporated through different food ingredients, depending on the formulation. However, adding these ingredients can affect the texture, flavour, stability, and overall acceptability of chocolate. This review examines the nutritional contributions of these ingredients and discusses formulation approaches reported in published research. It also considers important quality parameters and the challenges involved in developing chocolate with improved nutritional value without compromising its sensory characteristics. The review aims to support further research into the development of nutritionally improved chocolate products.

KEYWORDS— Healthy chocolate, functional ingredients, oats, flaxseed, nuts, dietary fibre, nutritional improvement, chocolate formulation.

I. INTRODUCTION

Chocolate is a widely consumed food product valued for its characteristic flavour, aroma, and texture. Its nutritional composition depends on the ingredients used and the proportions in which they are added. Although conventional chocolate provides energy, its sugar and fat content can vary considerably between products. This has encouraged interest in developing chocolate formulations that offer improved nutritional value while retaining the sensory qualities that consumers enjoy. One possible approach is to incorporate functional ingredients such as oats, flaxseed, nuts, and dietary fibre into chocolate formulations [1,3,6].

Functional ingredients have gained attention because they can contribute nutrients that may be limited in conventional food formulations. Oats are a source of dietary fibre, including beta-glucan, while flaxseed contains alpha-linolenic acid, an omega-3 fatty acid, and fibre [7,8,10]. Nuts provide unsaturated fats, protein, vitamins, and minerals, depending on the type used [13]. Dietary fibre can also be obtained from suitable plant-based ingredients and incorporated into food products to increase their fibre content [20,21]. Including these ingredients in chocolate may improve its nutritional composition; however, the actual benefits depend on the ingredients, their quantities, and the overall formulation. Therefore, their selection and incorporation need to be considered carefully to maintain the quality and acceptability of the final product [14-18].

Despite the potential nutritional advantages, incorporating functional ingredients into chocolate can present several formulation challenges. Ingredients such as oats, flaxseed, nuts, and additional sources of dietary fibre may change the product's texture, flavour, hardness, and processing characteristics [15-18]. The amount and type of ingredient used can influence how well it blends with the chocolate base and whether the final product remains acceptable to consumers. Maintaining stability and a pleasant sensory experience is therefore important when developing nutritionally improved chocolate. For this reason, formulation strategies should consider not

only the nutritional contribution of the added ingredients but also their effects on the quality and acceptability of the finished product [1,2,6].

Although research has explored the use of different plant-based ingredients in chocolate, developing a product with improved nutritional value while maintaining its quality remains an important consideration. Previous reviews have discussed chocolate fortification, functional ingredients, and the technological challenges associated with their incorporation [1-3]. Building on this research, the present review focuses on oats, flaxseed, nuts, and dietary fibre as potential ingredients for improving the nutritional composition of chocolate. It examines their nutritional contributions, approaches used to incorporate them into chocolate, and the effects they may have on physicochemical properties and sensory acceptability. By bringing these aspects together, the review aims to identify important considerations for the future development of nutritionally improved chocolate products [1-3, 14-18].

II. NUTRITIONAL PROFILE OF CHOCOLATE

Chocolate is primarily prepared from cocoa solids, cocoa butter, and sugar, while milk chocolate also contains milk ingredients. Its nutritional composition varies according to the type of chocolate, cocoa content, and proportions of sugar and fat used in manufacturing. Cocoa contains naturally occurring bioactive compounds, including polyphenols and flavonoids, as well as methylxanthines such as theobromine and caffeine [2,4,5].

Cocoa butter contributes substantially to the fat content of chocolate and influences its texture, melting behaviour, and mouthfeel. Its major fatty acids include palmitic acid, stearic acid, and oleic acid. The proportions of these fatty acids may vary according to the origin of the cocoa beans and the composition of the finished chocolate [5].

Cocoa also contains minerals and dietary fibre, while its polyphenol content depends on the cocoa material and the processing conditions used during chocolate manufacture. Processing steps can influence the quantity and composition of these compounds in the final product [4-6, 20].

Although chocolate can provide certain nutrients and bioactive compounds, it may also contain substantial amounts of added sugar and fat. Its nutritional value should therefore be considered in relation to its ingredients, formulation, and serving size. Incorporating oats, flaxseed, nuts, or suitable sources of dietary fibre may improve selected aspects of its nutritional composition [7,10,13,20]. However, the effects of these additions must be assessed alongside changes in texture, flavour, stability, and consumer acceptability [14-18].

III. FUNCTIONAL INGREDIENTS IN CHOCOLATE

Functional ingredients are incorporated into food products to improve their nutritional composition or provide specific desirable properties. In chocolate, plant-based ingredients such as oats, flaxseed, nuts, and dietary fibre have attracted interest because they can contribute additional nutrients. However, their suitability depends on their composition, quantity, and interaction with the chocolate base [1–3, 6].

A. Oats

Table 1: Taxonomic Classification of Oats

Rank	Scientific classification
Kingdom	*Plantae*
Division	*Magnoliophyta*
Class	*Liliopsida*
Order	*Poales*
Family	*Poaceae*
Genus	*Avena*
Species	*Avena sativa L.*



Fig 1: Oats [Avena sativa L.]

Oats are a valuable source of dietary fibre, particularly beta-glucan, a soluble fibre that has been studied for its role in maintaining normal blood cholesterol levels. They also provide carbohydrates, protein, and other nutrients [7, 8, 26]. Incorporating oats into chocolate may increase its fibre content and introduce a different texture. However, the particle size and quantity of oats can influence the smoothness, hardness, and overall acceptability of the finished product [9, 18].

Oats also contain proteins, unsaturated fatty acids, minerals, and phenolic compounds that contribute to their nutritional value. Among their bioactive components, beta-glucan is particularly important because it is a soluble dietary fibre associated with maintaining normal blood cholesterol levels and moderating post-meal blood glucose responses [7, 8, 26]. The functional properties of oats depend on their form, particle size, and processing conditions. Oat flour may blend more uniformly into a chocolate mixture, whereas rolled or coarsely ground oats can provide a noticeable texture. However, excessive addition may affect smoothness, hardness, and consumer acceptability. Therefore, the amount and particle size of oats should be carefully considered when developing fibre-enriched chocolate formulations [18].

B. Flaxseed

Table 2: Taxonomic Classification of Flaxseeds

Rank	Scientific classification
Kingdom	*Plantae*
Division	*Magnoliophyta [Flowering plants]*
Class	*Magnoliopsida* [Dicotyledons]
Order	Malpighiales
Family	Linaceae
Genus	*Linum*
Species	*Linum usitatissimum L.*



Fig 2: Flaxseeds [Linum usitatissimum L.] (Tarazevich, 2021)

Flaxseed is known for its nutritional content, including alpha-linolenic acid, a plant-derived omega-3 fatty acid, dietary fibre, and lignans. These components make flaxseed an interesting ingredient for the development of nutritionally improved foods [10–12]. The incorporation of flaxseed into food products, including chocolate, may increase their contribution of dietary fibre and plant-based fatty acids, although the effects depend on the formulation and ingredient quantity [10–12, 19]. Nevertheless, the quantity and form of flaxseed used should be considered because its flavour, particle size, and oil content may affect the texture and storage stability of the product [14].

C. Nuts

Table 3: Taxonomic Classification of Almonds and Walnuts

Rank	Scientific Classification [Almonds]	Scientific Classification [Walnuts]
Kingdom	*Plantae*	*Plantae*
Division	*Magnoliophyta*	*Magnoliophyta*
Class	*Magnoliopsida*	*Magnoliopsida*
Order	*Rosales*	*Fagales*
Family	*Rosaceae*	*Juglandaceae*
Genus	*Prunus*	*Juglans*
Species	*Prunus dulcis (Mill.) D.A.Webb*	*Juglans regia L.*



Fig 3: Almonds and Nuts

Nuts provide unsaturated fatty acids, plant protein, dietary fibre, vitamins, and minerals [13]. Almonds, walnuts, and hazelnuts are examples of nuts that may be considered when developing chocolate products with additional nutritional value. Depending on the type and quantity used, nuts may also influence the flavour, texture, and energy content of chocolate. Their incorporation requires attention to particle size, ingredient distribution, and the possibility of rancidity during storage [1, 13].

D. Dietary Fibre

Dietary fibre is an important component of a balanced diet and can be obtained from various plant-based ingredients. Depending on the source, fibre ingredients may contribute soluble fibre, insoluble fibre, or a combination of both. Their incorporation into chocolate may help increase its fibre content [20, 21]. However, the effects on texture, viscosity, flavour, and processing behaviour depend on the type and quantity of fibre used. Therefore, appropriate ingredient selection is necessary to balance nutritional improvement with product quality [6, 16, 17].

Overall, oats, flaxseed, nuts, and dietary fibre offer different nutritional contributions that may be useful in chocolate development. Their inclusion should be supported by published research and evaluated in terms of nutritional composition, physical properties, sensory acceptability, and storage stability [1–3, 14–18].

IV. FORMULATION STRATEGIES FOR HEALTHY CHOCOLATE

The development of nutritionally improved chocolate requires careful selection of functional ingredients and consideration of their effects on the chocolate base. Published reviews describe the incorporation of plant-derived ingredients and other functional substances to improve nutritional composition while maintaining acceptable product quality [1,3,6].

A. Selection and Preparation of Ingredients

The selection of ingredients depends on their nutritional composition, availability, safety, and compatibility with chocolate. Oats may be used as flakes or in powdered form, while flaxseed can be incorporated as whole seeds or ground material. Nuts may be added in chopped or powdered form, depending on the desired texture. Suitable fibre-rich ingredients can also be considered to increase the dietary fibre content. Ingredient preparation and particle size should be considered because they may influence the texture and uniformity of the finished product [7,10,13,15,18].

B. Incorporation into the Chocolate Base

Functional ingredients can be incorporated into a chocolate base using approaches appropriate to the ingredient and manufacturing process. Solid ingredients such as oats, ground flaxseed, and chopped nuts may be dispersed through the chocolate mass. Other ingredients, including selected fibre sources, may require additional consideration because they can alter viscosity, flow behaviour, and texture. Uniform distribution is important to obtain a consistent product. The suitability of each approach should be assessed using evidence from published studies [2,6, 15-18].

C. Optimisation of Ingredient Concentration

The quantity of each functional ingredient can influence both nutritional composition and sensory acceptability. Increasing the amount of an ingredient does not necessarily improve the overall quality of chocolate, as excessive additions may produce undesirable changes in flavour, hardness, smoothness, or appearance. Therefore, studies of fortified chocolate commonly consider the balance between nutritional improvement and product acceptability. The most suitable concentration depends on the ingredient, the chocolate base, and the intended product characteristics [14-18, 22].

D. Processing and Storage Considerations

Published research on chocolate fortification has investigated different plant-derived ingredients, bioactive substances, and fibre-related ingredients, including grape pomace and plant extracts [22–24]. Chocolate processing conditions can influence its texture, appearance, and stability. Factors such as mixing, particle size, temperature control, and storage conditions should be considered when developing a fortified product. Ingredients containing unsaturated fats, including flaxseed and certain nuts, may be susceptible to oxidative deterioration. Appropriate packaging and storage conditions can help maintain product quality. The effects of processing and storage should be evaluated rather than assumed [5,10,13,14].

E. Comparison of Formulation Approaches Reported in Literature

Several studies have explored ways to improve the nutritional value of chocolate by adding ingredients such as oats, flaxseed, dietary fibre, and other plant-based substances. Each approach offers different benefits, but the final quality of chocolate also depends on the ingredients used and how they are processed [1, 2, 14, 17, 18].

Oats are a useful source of dietary fibre, particularly beta-glucan, whereas flaxseed provides alpha-linolenic acid and other valuable compounds. Nuts can add protein, minerals, and unsaturated fats.

Dietary fibre from sources such as resistant starch may also help increase the fibre content of chocolate. However, adding these ingredients can affect the taste, texture, and appearance of the final product [7, 10, 13, 17, 18].

Most studies focus on a particular ingredient or formulation approach. The present review brings these four ingredient groups together and compares their nutritional benefits along with practical considerations such as texture, sensory acceptability, processing, and storage. This comparison helps identify the possible advantages and limitations of each ingredient and may support the selection of suitable ingredients for future healthy chocolate formulations. Further experimental studies are needed to determine the most appropriate combinations and quantities.

Table 4: Comparative Analysis of Functional ingredients used in Healthy Chocolate

Functional Ingredients	Major Nutritional Components	Potential Nutritional Contributions	Formulation Challenges
Oats	Dietary Fibre, beta glucan, protein, carbohydrates	May improve fibre content and nutritional profile	May affect texture and smoothness
Flaxseeds	Alpha –linolenic acid [ALA], lignans, protein and fibre	Provides plant-based omega-3-fatty acid and fibre	Characteristic flavour and susceptibility to oxidation
Nuts [Almonds& Walnuts]	Unsaturated fats, proteins, fibre, vitamins and minerals	May improve nutritional composition and provide unsaturated fatty acids	Allergen concerns, texture changes and oxidation
Dietary Fibres	Non-digestible carbohydrates, depending on source	Increase fibre content and may support normal bowel function	May affect texture, moisture interactions and sensory acceptability

V. EVALUATION OF HEALTHY CHOCOLATE

The evaluation of nutritionally improved chocolate is important to determine whether the addition of functional ingredients improves its nutritional composition without adversely affecting product quality. The evaluation parameters selected depend on the formulation, ingredients, and objectives of the research. Previous studies on fortified chocolate have examined nutritional, physicochemical, sensory, and stability-related characteristics to assess the effects of ingredient incorporation [1–3, 14–18].

A. Nutritional Parameters

The nutritional quality of healthy chocolate can be evaluated by determining its moisture content, protein, fats, carbohydrate, and dietary fibre content. These parameters help assess the nutritional composition, quality, and suitability of the developed product.

1. Moisture Content: Moisture content is the amount of water present in a food product, expressed as a percentage of its total weight. It influences the texture, stability, and shelf life of chocolate.

2. Protein Content: Protein content refers to the amount of protein present in a food product. Proteins are made up of amino acids and contribute to growth, tissue repair, and the nutritional value of food.

3. Fat Content: Fat content represents the total amount of fats present in a food product. Fat influences the texture, melting behaviour, mouthfeel, and energy value of chocolate.

4. Carbohydrate Content: Carbohydrate content refers to the amount of carbohydrates present in a food product, including sugars and starches. Carbohydrates contribute to the energy value and, depending on their type, the sweetness and texture of chocolate.

5. Dietary Fibre Content: Dietary fibre content represents the amount of dietary fibre present in a food product. Dietary fibre is not completely digested in the human small intestine and may support normal bowel function. Its incorporation can increase the fibre content of chocolate.

Nutritional improvement should therefore be demonstrated through appropriate analytical methods rather than assumed from the addition of functional ingredients [15, 17, 20]

B. Physicochemical Properties

Physicochemical evaluation may include appearance, colour, hardness, texture, melting behaviour, and moisture content. These properties influence the quality and consumer acceptance of chocolate. The addition of oats, flaxseed, nuts, or fibre-rich ingredients may change the physical characteristics of the product. The extent of these changes depends on the type and quantity of ingredient incorporated [14–18].

C. Sensory Evaluation

Sensory evaluation is used to assess characteristics such as colour, aroma, taste, texture, and overall acceptability. These characteristics are particularly important when developing chocolate with added functional ingredients because changes in flavour or mouthfeel may affect consumer preference. Properly designed sensory studies can help identify formulations that provide a suitable balance between nutritional composition and eating quality [15, 18, 22].

D. Stability and Storage Evaluation

Storage evaluation helps determine whether the product retains its quality over time. Relevant parameters may include changes in appearance, texture, flavour, moisture, and signs of fat oxidation. Ingredients containing unsaturated fatty acids may increase the importance of monitoring oxidative stability. Suitable packaging and storage conditions should be considered when evaluating the quality of nutritionally improved chocolate [1, 14].

Overall, nutritional, physicochemical, sensory, and stability evaluations provide complementary information about fortified chocolate. Using appropriate methods allows researchers to assess the effects of functional ingredients and identify potential limitations. The selected tests should be justified by the study objectives and supported by relevant scientific literature [1–3, 15–18].

VI. CHALLENGES AND FUTURE PERSPECTIVES

The development of healthy chocolate offers opportunities to improve its nutritional composition through the incorporation of functional ingredients. However, several challenges must be considered to achieve nutritional improvement without compromising product quality [1–3, 28, 29].

A. Challenges in Product Development

One major challenge is maintaining the characteristic taste, texture, and appearance of chocolate after adding functional ingredients. Oats, flaxseed, nuts, and fibre-rich ingredients may alter smoothness, hardness, flavour, and processing behaviour. The extent of these changes depends on the ingredient type, particle size, and quantity used. Careful ingredient selection and formulation optimization are therefore important [14–18].

B. Nutritional and Stability Considerations

Although functional ingredients may contribute additional nutrients, their inclusion does not automatically make a chocolate product healthier. The overall nutritional composition, including added sugar, total fat, energy content, and portion size, should also be considered [2, 4, 5]. Ingredients rich in unsaturated fats may be susceptible to oxidation, making stability and appropriate storage important considerations during product development [10, 11, 13].

C. Future Research Opportunities

Future research may investigate different combinations of oats, flaxseed, nuts, and suitable fibre sources to identify formulations that balance nutritional composition with sensory acceptability. Researchers could also explore reduced-sugar approaches, improved ingredient dispersion, and packaging methods that help preserve product quality [1–3, 6, 28, 30]. Well-designed studies should report ingredient quantities, processing conditions, evaluation methods, and relevant results so that findings can be compared reliably.

Overall, further research is needed to establish which combinations of functional ingredients provide meaningful nutritional benefits while maintaining acceptable quality, stability, and consumer preference. Evidence from controlled studies will be important for guiding the development of nutritionally improved chocolate products [3, 14–18].

VII. CONCLUSION

Healthy chocolate represents a promising approach to improving the nutritional composition of conventional chocolate through the incorporation of functional ingredients. Oats, flaxseed, nuts, and dietary fibre can contribute additional nutrients, including fibre, plant-based fatty acids, and other beneficial components. However, the nutritional value of the final product depends on the ingredients selected, their quantities, and the overall formulation [7, 10, 13, 20].

The literature indicates that incorporating functional ingredients into chocolate requires careful consideration of physicochemical properties, sensory acceptability, and storage stability. Although ingredient fortification may improve selected nutritional characteristics, excessive additions or unsuitable processing conditions may adversely affect texture, flavour, and consumer preference. Therefore, nutritional improvement should be balanced with product quality and acceptability [1–3, 14–18].

Future research should focus on identifying suitable ingredient combinations, optimizing their concentrations, and evaluating their effects through appropriate nutritional, physicochemical, sensory, and stability studies. Overall, the development of nutritionally improved chocolate offers potential for creating products with a more favourable nutritional profile while retaining the sensory qualities expected by consumers [1–3].

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