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Use of Plant Seeds in Cheese Production

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ABSTRACT

Cheese is a widely consumed and nutritious staple meal created through several methods and components globally. The utilization of alternate botanical sources in cheese production has gained prominence in recent years. Plant seeds are noteworthy for cheese manufacturing due to their rich array of nutritional and functional components. The study aims to investigate plant seeds utilized in functional cheese production and to illuminate research on new product creation. Seeds can be utilized directly, as well as flour, extract, gum, mucilage, or oils derived from seeds in cheese production. The incorporation of plant seeds in cheeses enhances the levels of vitamins, minerals, dietary fiber, vital fatty acids, as well as phenolic and antioxidant compounds. The incorporation of plant seeds enhances the physicochemical properties of certain cheeses, augments antimicrobial efficacy, positively influences oxidative stability during storage, lowers production costs, inhibits surface mold formation as a coating agent, and improves cheese texture and sensory attributes. This study examined the incorporation of Chia, flaxseed, basil, sesame, black cumin, quinoa, *Moringa oleifera* seeds, and various other seeds into cheese. The impact of these seeds on cheese quality was examined.

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Introduction

In recent years, the development of functional characteristics in various food products has become increasingly important in protecting and promoting human health, as well as illness prevention. 'Functional foods' are food products that claim to offer a variety of benefits and physiological impacts on human health. In addition to providing the human body's fundamental nutritional requirements, these foods can be utilized to treat a variety of acute and chronic disorders (Ahmad et al., 2022).

Foods with potential health benefits can often be improved in functioning by adding other foods with positive qualities. Furthermore, the concentration of detrimental components in the primary meal can be reduced without supplementing, or there can be a partial shift between hazardous and beneficial components. As a result, functional meals can be defined as non-prescription nutrition that can help with treatment (Shiby and Mishra, 2013). A wide range of products are developed and introduced in the food industry to achieve this goal.

Cheeses undergo multiple processes, and various foods and additives are incorporated to enhance their possible health advantages and certain technological attributes. Seeds are commonly utilized to enhance the functional properties of cheeses, which hold significant nutritional value and are incorporated into most diets. Plant seeds provide functional qualities due to substances including omega-3 and omega-6 fatty acids, dietary fiber, essential amino acids, lignans, phenolic compounds, and antioxidants. The bioactive constituents present in plant seeds are linked to significant nutraceutical and therapeutic benefits (Dotto and Chacca, 2020). Functional products positively influence metabolic processes, lowering blood glucose and cholesterol levels, enhancing immunological function, and aiding in cancer prevention.

They possess anti-allergic, anti-inflammatory, antithrombotic, antibacterial, stimulant, antispasmodic, and antioxidant properties (Stanislav et al., 2019). This study examined plant seeds and their application methods to enhance the functional and/or technological properties of cheeses. Thus, it was aimed to contribute to cheese producers and the academic community.

Plant Seeds and Application Methods Used to Improve the Functional and/or Technological Properties of Cheeses

Chia Seed

Chia seed (*Salvia hispanica* L.) is a plant species utilized for therapeutic and nutritional uses by numerous civilizations since antiquity (De Falco et al., 2017). The

seed's origin is documented as Mexico and Guatemala. Chia seed is regarded as a functional food due to its constituent components (Muñoz et al., 2013; Suri et al., 2015; Dinçoğlu and Yeşildemir, 2019). It is a food source rich in dietary fiber, protein, vitamins and minerals (Grancieri et al., 2019; Agarwal et al., 2023). It is also reported to be the main known plant source of α-linolenic acid (ALA) (Schettino et al., 2017). Chia seeds have been shown to provide health benefits, including controlling blood cholesterol levels, hypotensive, hypoglycemic, antioxidant, antibacterial, and immunostimulating properties (Kulczyński et al., 2019; Katunzi-Kilewela et al., 2021; Motyka et al., 2022). The beneficial effects of chia seed in nutrition on chronic diseases such as obesity, cardiovascular disease, diabetes, and cancer have led to a surge in its use in recent years (Poudyal et al., 2012; Valdivia-López and Tecante, 2015). Chia seeds are commonly added to dishes as a whole. These seeds are added directly to foods such as milk, yogurt, salad, fruit, granola, cake, and bread. In addition, mucilages and oils obtained from the seeds are used to improve the physicochemical qualities of foods (Muñoz-Tébar et al., 2019; Chiang et al., 2021).

Because chia seeds may be used in a variety of dishes, they are becoming increasingly popular in cheeses. Table 1 summarizes information on the use of Chia seeds in different cheeses. Boldori et al. (2020) made cream cheese by combining 10% chia seeds with semi-skimmed and skimmed milk. According to the findings of this investigation, samples made with skimmed milk and chia seeds were not sensory satisfactory. On the other hand, it was discovered that cream cheeses made with semi-skimmed milk and chia seeds had great sensory acceptability and increased functional characteristics.

According to the findings of a study in which 3% Chia, quinoa, and tef seeds were used to make spreadable cheese, cheeses made with quinoa and tef seeds had higher protein content than cheese made with chia seeds (Guneser et al., 2023). Furthermore, the findings of this study revealed that cheeses created with the inclusion of seeds included higher quantities of volatile chemicals than the control sample, implying that these seeds could be used in the development of functional cheeses.

Another study employed Chia seeds to make soft cheese, adding 1%, 2%, and 3% Chia seed powder to the cheese (Bakr et al., 2024). This study found that adding seed powder to cheeses increased their physicochemical properties, particularly their protein and mineral content. The cheese with 2% seed powder was found to have the highest sensory acceptance.

Safaa (2017) made soft cheese by combining 4%, 8%, 12%, and 16% chia flour. It was discovered that chia flour boosted antibacterial capacity in cheeses, and that adding 8% chia flour resulted in optimal organoleptic qualities. Another study used 1.5% and 3.0% chia seed nanocapsules in ricotta cheese (Hosseini et al., 2023). Chia seed nanocapsules were found to improve cheese's functional characteristics and oxidative capability during storage.

There have also been research looking into the usage of chia seed oil in cheese making. A study by Muñoz-Tébar et al. (2019) found that adding 2% oil from chia seeds to sheep cheese improved its physicochemical quality and enhanced its ALA concentration. Ullah et al. (2018) found that lowering the milk fat used in Cheddar cheese production and adding 2.5%, 5%, 7.5%, and 10% Chia oil increased the cheese's antioxidant characteristics. The study found that adding Chia oil boosted the amount of omega-3 fatty acids and phenolic compounds in the cheese. Cardoso et al. (2020) discovered that using chia seed oil as a source of unsaturated fatty acids in Grana Padano and Mozzarella cheeses significantly reduced the cheese's flavor. It was determined that using chia seed oil in microcapsules improved sensory acceptance.

Flaxseed

Flaxseed (*Linum ussitassimum* L.) is a plant seed that has been used for its health advantages since ancient times (Tolkachev and Zhuchenko, 2004). Flaxseed is classified as a functional food because of the possible health advantages provided by bioactive components such as high-quality protein, ALA, lignans, and dietary fiber (Oomah, 2001; Gebauer et al., 2006; Raghuwanshi et al., 2019). It contains antioxidant, antidiabetic, and anti-cancer effects (Raghuwanshi et al., 2019). Its high ALA content may also help to protect the cardiovascular system (Rabetafika et al., 2011). Flaxseed can be utilized as a functional food ingredient on its own or in oil form. Flaxseed and flaxseed oil are commonly used in bakery items, fruit juices, pasta, meat, and dairy products (Raghuwanshi et al. 2019). Flaxseed can be used in the manufacturing of milk and dairy products for a variety of reasons, including increasing protein content, decreasing milk fat content, and lowering glycemic index. There are many studies on the use of flaxseed in cheeses (Table 2).

Costa et al. (2012) utilized 1%, 2.5%, 5%, and 10% flaxseed flour to make Brazilian cheese rolls. According to the findings of this investigation, the cheese rolls with the highest sensory approval rate contained 2.5% seed flour. It was also shown that cheese rolls supplemented with flaxseed flour were high in omega-3 and omega-6.

Table 1. Use of chia seeds in cheeses

Cheese Used	Usage rate	Examined properties	Reference
Soft cheese	%4-16	Microbiological	Safaa (2017)
Cheddar cheese	%2.5-10	Omega fatty acids, phenolic compounds, and lipolysis	Ullah et al. (2018)
Sheep cheese	%2	Physicochemical, antioxidant capacity	Muñoz-Tébar et al. (2019)
Cream cheese	%10	Physicochemical, sensory	Boldori et al. (2020)
Spreadable cheese	%3	Physicochemical, sensory, rheological	Guneser et al. (2023)
Ricotta cheese	%1.5-3	Antioxidant activity	Hosseini et al., 2023
Soft cheese	%1-3	Physicochemical, microbiological, and sensory	Bakr et al. (2024)

Table 2. Use of flaxseed in cheeses

Cheese Used	Usage rate	Examined properties	Reference
Cheese spread	%5-20	Physicochemical, volatile fatty acids	Hassan et al. (2007)
Brazilian cheese rolls	%1-10	Fatty acid, sensory	Costa et al. (2012)
White cheese	%2	Chemical, sensory, microbiological	Mahrous et al. (2014)
Quesa blanco	%1.27	Physicochemical, microbiological	Gurdian et al. (2017)
White cheese	%0-100	Physicochemical, sensory	Joodi Attar et al. (2018)
Spreadable cheese	%25-100	Chemical and biological	Ahmed et al. (2019)
Cheese paste	%8-12	Microbiological	Lialyk et al. (2019)
Cheddar cheese	%0.75-1.25	Microbiological, physicochemical, rheological, sensory	Soleimani et al. (2020)
Cream cheese	%1	Physicochemical, rheological, sensory, microstructural	Shahraki et al. (2023)

Flaxseed oil was utilized at 25%, 50%, 75%, and 100% rates in a trial to replace milk fat in the manufacturing of spreadable cheese (Ahmed et al., 2019). It was discovered that linoleic, linolenic, and arachidonic acids increased dramatically in cheeses made with flaxseed oil. In addition, the cheeses prepared in this study were fed to rats and their metabolic effects were examined. Total blood cholesterol levels fell in rats fed cheeses containing 75% flaxseed oil. Another study found that utilizing large volumes of flaxseed oil (96.01%) in the making of white cheese increased textural and sensory qualities (Joodi Attar et al., 2018).

In addition, numerous studies have shown that using flaxseed oil in various quantities in the creation of low-fat cream cheese or white cheese might be useful in reducing the amount of fat consumed on a daily basis (Abd Elhamid, 2017; Shahraki et al., 2023). In one study, cheese made from milk with 2% flaxseed oil added to reduce milk fat was found to be lower in fat than typical cheese (Mahrous et al., 2014).

Bermúdez-Aguirre and Barbosa-Cánovas (2011) found that adding omega-3 from fish oil and flaxseed oil to Queso fresco, cheddar, and mozzarella cheeses increased their omega-3 content. Although fish oil has a larger omega-3 concentration, according to sensory study results, the most popular cheeses contained omega-3 sources derived from flaxseed. As a result, it was discovered that flaxseed oil is an essential option for a plant omega-3 supply.

Although flaxseed oil contributes to cheese fat content, another study found that lipid oxidation increased in cheeses containing 1.27% flaxseed oil (Gurdian et al., 2017). This is assumed to be connected to the oxidative sensitivity of polyunsaturated fatty acids contained in flaxseed (Zajac et al., 2017).

The usage of flaxseed mucilage in cheese production has also been called into doubt. Akl et al. (2020) employed flaxseed mucilage as a prebiotic and fat substitute in cream cheese. Total dry matter, protein, and ash content, as well as viscosity and antibacterial impact, were found to rise in cheeses made with mucilage. The inclusion of mucilage improved the texture and sensory qualities of the cheese. Similarly, another study found that using flaxseed in the manufacturing of Gouda-type hard cheese improves its antibacterial properties.

Flaxseed can be used in cheeses to increase functional properties, lower costs, and extend shelf life. Studies utilizing 5%, 10%, and 20% flaxseed powder in processed cheeses found that adding 10% flaxseed powder can assist lower cheese manufacturing costs while also providing the proper textural structure (Hassan et al., 2007).

Cheeses can be kept fresher for longer by using flaxseed gum. A study found that coatings made from flaxseed gum, casein, and chitosan for the preservation of Mongolian cheese are resistant to microbes. As a result, flaxseed can also be utilized to create antibacterial edible coatings. Another study evaluating the use of flaxseed mucilage and xanthan gum as coating ingredients in cheddar cheese yielded similar results (Soleimani et al., 2020). In this study, 0.5% xanthan gum and 0.75%, 1%, and 1.25% flaxseed mucilage were utilized. Coating with xanthan gum was found to enhance the mold and yeast population of cheeses during storage, whereas coatings made with 1.25% flaxseed mucilage supplied the appropriate qualitative and organoleptic qualities. Lialyk et al. (2019) found that curd cheeses produced with 8%, 10%, and 12% flaxseed oil had a shorter storage time and could only be kept cold for 7 days. Based on all of this research, it can be concluded that different types of flaxseeds can alter the storage process in a variety of ways.

Basil Seed

Basil (*Ocimum basilicum* L.), an annual and aromatic plant belonging to the *Lamiaceae* family, is a plant seed that can grow in many parts of the world and is used for many purposes. Its common areas of use are the food, pharmaceutical, and cosmetic industries (Calderón Bravo et al., 2021). In addition to adding basil seeds to many dishes as flavoring agents, the gum obtained from this seed is widely used in the food and pharmaceutical sectors as an emulsifier or stabilizer. The thickening, gelling, and binding properties of this gum expand its area of use (Kim et al., 2020). The fact that its seeds are rich in dietary fiber makes its use widespread in foods as a functional ingredient (Calderón Bravo et al., 2021). Information on the use of basil seed in different cheeses is given in Table 3.

Basil seeds are widely utilized as a covering material in cheese making. According to the findings of a study in which 1% basil seed gum was employed in cheese manufacturing, cheese production was feasible with lesser protein, higher moisture content, and cheaper cost (Hosseini-Parvar et al., 2015). It was also discovered that cheeses made with basil seed gum had a high hardness and low melting capacity. Similarly, the study that employed 0.25% and 0.5% basil seed gum in cream cheese production found that the cheese texture stiffened (Portaghi et al., 2023).

Table 3. Use of basil seed in cheeses

Cheese Used	Usage rate	Examined properties	Reference
Processed cheese	%1	Textural, rheological, microstructural	Hosseini-Parvar et al. (2015)
Cheddar cheese	%0.25-0.5	Antimicrobial	Kheirkhah-Foghara et al. (2021)
Lactic cheese	%1-5	Microbiological, physicochemical, sensory	Kolaleh et al. (2022)
Riccotta cheese	%0.4-0.8	Antioxidant, antibacterial	Azarashkan et al. (2022)
Cream cheese	%0.25-0.5	Physicochemical, textural, sensory	Portaghi et al. (2023)

Table 4. Use of sesame seed in cheeses

Cheese Used	Usage rate	Examined properties	Reference
Soft cheese	%4-12	Rheological, textural, microstructural	Lu et al. (2010)
Fresh cheese	%8	Chemical, rhelogical, microstructural	Lu et al. (2012)
Kareish cheese	%1-5	Chemical, microbiological, organoleptic	El-Sayed et al. (2016)
Labneh cheese	%2-6	Physiochemical, microbiological, organoleptic	Aly et al. (2020)
Ras's cheese	%1-3	Chemical, microbiological, organoleptic	Gafour et al. (2020)

Another study used basil seed gum as a coating material in cheeses, with 1%, 2.5%, and 5% cumin extract (Kolaleh et al., 2022). The study's findings revealed that cheese coatings with 1% and 2.5% additions had the optimum sensory quality ratio. This edible covering was also shown to drastically reduce the number of germs and molds in cheeses.

However, it has been argued that it is a viable option for the manufacturing of low-cost cream cheese. The findings of the study in which basil seed gum was added to Iranian white cheese revealed that basil seed gum could be a promising alternative for soft cheese production (Baghdadi et al., 2018). This study found that basil seed gum initially produced a hard texture but softened on the 60th day of storage.

It was determined that the antibacterial and antioxidant capacity of ricotta cheese produced by adding encapsulated broccoli sprout extract nanoliposomes to basil seed gum increased (Azarashkan et al., 2022). Therefore, it was stated that it is suitable for use in cheeses as a natural preservative. In another study where basil seed was used as a coating in cheddar cheese, basil seed mucilage containing 0.25% and 0.5% zinc oxide nanoparticles was used (Kheirkhah-Foghara et al., 2021). The results of this study also provide findings that mold formation on the surface was prevented.

Sesame Seed

Sesame (*Sesamum indicum* L.) is one of the most important oilseeds due to its nutritional content and widespread use in foods. The high protein and essential amino acids in its content form the basis of the functional qualities of this seed. Sesame seeds have an average of 50% oil and 20% to 30% protein (Chung et al., 1995; Kanu et al., 2007; Hahm et al., 2009).

In addition, the seeds are rich in vitamins, minerals, fibers, and various organic compounds. Omega-6, vitamin E, and calcium are stated as prominent contents (Singh et al., 2016). Sesame seed, which has high phenolic compounds and antioxidant content (Ali et al., 2007), is generally grown for use in the food sector.

Sesame can be used directly as a spice in various dishes in many national cuisines. Sesame seed is also evaluated for its various by-products. Sesame flour and sesame oil are the leading ones among these by-products.

Sesame seeds are utilized not only for traditional purposes, but also to increase the functioning properties of cheese (Table 4). Slozhenkina et al. (2019) investigated the influence of 1%, 3%, and 5% sesame seeds on cheese sensory attributes and concluded that 3% sesame seeds are appropriate for producing functional cheese with good sensory acceptability. Similarly, another study found that sesame seeds have functional usage potential and good sensory acceptability in the manufacturing of Mudaffara cheese (Farah and El-Zubeir, 2019). In the study using 2%, 4%, and 6% sesame seed powder in the production of functional labneh cheese, it was determined that the seed powder increased the protein and ash content (Aly et al., 2020).

In the studies where 4%, 8%, and 12% sesame seed protein isolate was used in soft cheese production, it was determined that tissue deterioration occurred in the cheeses and had a negative effect in terms of texture (Lu et al., 2010). Similarly, it was determined that cheeses produced with 8% sesame seed protein isolate had longer coagulation times and increased hardness, adhesiveness and meltability during storage (Lu et al., 2012).

In a study where oleosomes extracted from sesame seeds were used in cheese production at 25%, 50%, 75%, and 100% levels, it was reported that the use of 75% oleosomes reduced the fat content and preserved tissue integrity (Sheikh et al., 2023).

Studies have been conducted on the use of sesame shells, a by-product, in cheeses. El-Sayed et al. (2016) used 1%, 2%, 3%, 4%, and 5% sesame shells in the production of Kareish cheese. According to the data obtained in this study, increasing the amount of sesame shells increased the protein, ash, fiber and vitamin A content in the cheese. In another study where 1%, 1.5%, 2%, and 3% sesame shells were used in the production of Ras cheese, the addition of sesame shells similarly increased the fat, protein, ash and vitamin A content of the cheese (Gafour et al., 2020).

Black cumin

Black cumin (*Nigella sativa* L.) is one of the prominent seed spices with its traditional medicine and culinary uses. The protein, essential fatty acids, vitamins, and minerals found in black cumin, as well as its antioxidant, anti-inflammatory, anti-cancer, and antihypertensive health potential, make its use widespread for both nutritional and

medical purposes (Kooti et al., 2016). Most of the functional qualities of black cumin are associated with thymoquinone, a component of volatile oil (Dubey et al., 2016). Black cumin, which is used in the form of volatile oil, paste, or powder for medical purposes, is generally used whole in kitchens. It is commonly added to bakery products as a flavoring agent. In Far Eastern and Indian cuisine, it can be added during the preparation of many dishes.

Various beneficial products are being created with black cumin oil, flour, pulp, or entire seeds. Table 5 provides information on the usage of black cumin seeds in various cheeses. Studies have consistently proven that black cumin's antibacterial and antioxidant properties are used. A study by Mahgoub et al. (2013) found that black cumin oil inhibited pathogen growth in Domiati cheese.

The study found that cold-pressed black cumin oil applied to Domiati cheese at 0.1% and 0.2% levels inhibited the growth of foodborne pathogens such *Staphylococcus aureus*, *Escherichia coli*, and *Listeria monocytogenes*. Another study that used black cumin oil as a preservative (Taherkhani et al., 2015) found that adding 0.4% black cumin oil to Gouda cheese during ripening had the greatest antimicrobial effect, indicating that it was a suitable plant source for use as a preservative and flavoring agent. Similarly, 0.2%, 0.4%, and 0.6% black cumin oil added to Edam cheese during ripening inhibited yeast and mold growth (Abdelmontaleb et al., 2020). The addition of 1% and 3% black cumin, as well as 0.1% and 0.3% black cumin oil, to cottage cheese produced antibacterial effects in this study. Another study found that 0.5%, 0.75%, and 1% black cumin improved antibacterial activity in soft cheeses (Al-Jumaili and Abdullah, 2019). According to the findings of a study in which *Bifidobacterium animalis*, *Lactobacillus casei*, and 0.1% and 2% black cumin seeds were used to make probiotic cottage cheese, the probiotic population increased (Rostami et al. 2018). Similarly, another study employed 2%, 2.5%, and 5% ground black cumin, as well as 2.5% and 5% black cumin oil, to make soft cheese (Al-Mousawi and Al-Rawi, 2009). This study found that adding black cumin had an antimicrobial impact on cheeses and increased their shelf life.

Furthermore, the use of black cumin in cheeses is not only for its preventive properties, but also to fill it with numerous nutrients and strengthen its physical structure. A study by Çakır and Çakmakçı (2018) found that adding 1% black cumin to Erzincan tulum cheese enhanced its protein, ash, and ripening index. Another study found that adding 0.1% and 0.2% black cumin oil enhanced the moisture in cheeses and could help avoid texture loss (Georgescu and Raita, 2019).

Quinoa Seed

Quinoa (Chenopodium quinoa Willd) has attracted attention as a functional food in recent years with its high protein and essential amino acid content. The fact that its nutritional content is richer than other grains and that it contains components beneficial to human health (Navruz-Varlı and Şanlıer, 2016) paves the way for its use in many products. In addition to its high protein content, it is also rich in carbohydrates, lipids, vitamins and minerals (Vidueiros et al., 2015). Quinoa can be used directly in salads and various desserts, and its flour is also used in the production of many products. The flour obtained by grinding quinoa can be used in various bakery products such as bread, pasta, noodles, and biscuits. At the same time, crackers prepared with quinoa flour are also evaluated as alternative snacks for celiac patients. In addition, quinoa seeds can also be used directly in soups or energy bars (Angeli et al., 2020).

Quinoa seed is utilized in a variety of ways to improve the functional properties of certain cheese kinds (Table 6). In a study where quinoa paste was utilized in cheese manufacturing (10, 20, 30, 40%), it was found that adding quinoa paste reduced protein, ash, and total volatile oil content in cheese (El-Dardiry et al.,2020). Furthermore, it was suggested that quinoa paste might be used as an alternative to reduce cheese production expenses. Similarly, several research (Karimpour et al., 2023a; Karimpour et al., 2023b) found that using quinoa seed in cheese production lowered the amount of protein. On the other hand, according to the findings of a study in which quinoa flour was used in soft cheese manufacturing (1%, 2%, 3%), there was an increase in cheese contents such as protein, fiber, ash, and antioxidant capacity with the inclusion of quinoa flour. Hassan et al. (2024) found that soft cheeses made with 2%, 4%, and 6% quinoa flour had better physical and sensory properties. El-Dardiry (2022) used germinated quinoa seeds in the production of Kareish cheese. It was reported that there was an increase in fiber, protein, minerals, vitamins, total phenolic compounds and antioxidant capacity in cheeses prepared with the addition of germinated seeds.

Table 5. Use of black cumin in cheeses

Cheese Used	Usage rate	Examined properties	Reference
Soft cheese	%2-5	Microbiological, sensory	Al-Mousawi and Al-Rawi (2009)
Domiati cheese	%0.1-0.2	Microbiological	Mahgoub et al. (2013)
Gouda cheese	%0.4	Microbiological	Taherkhani et al. (2015)
Erzincan tulum cheese	%1	Proteolysis, sensory, volatile profiles	Çakır et al. (2016)
Erzincan tulum cheese	%0-2	Microbiological, chemical, biochemical properties	Çakır and Çakmakçı (2018)
Soft cheese	%0.5-1	Chemical, sensory, microbiological	Al-Jumaili and Abdullah (2019)
Edam cheese	%0.2-0.6	Physicochemical, antioxidant activity, sensory	Abdelmontaleb et al. (2020)

Table 6. Use of quinoa seed in cheeses

Cheese Used	Usage rate	Examined properties	Reference
Cheese spread	%10-40	Physicochemical, microstructural	El-Dardiry et al. (2017)
Kareish cheese	%1-5	Chemical, rheological, microstructure, microbiological, sensory	El-Dardiry (2022)
Whey-free cheese	%0-9	Physicochemical, phenolic compounds, textural, microbiological, sensory	Karimpour et al. (2023a)
Whey-free cheese	%0-9	Physicochemical, proteolysis, textural profiles	Karimpour et al. (2023b)

Table 7. Use of *Moringa oleifera* seed in cheeses

Cheese Used	Usage rate	Examined properties	Reference
Cottage cheese	%0.5-2	Physicochemical, coagulating	Mahami et al. (2012)
Wara cheese	50-100 ml	Physicochemical, sensory, organoleptic	Orhevba and Taiwp (2016)
Full-fat, nonfat, soy milk cheese	2 g	Coagulating	Sánchez-Muñoz et al. (2017)
Curd cheese	%2	Physicochemical, coagulating	Ismail (2019)
Kareish cheese	%0.5-2.5	Physicochemical, microbiological, sensory	Hatem et al. (2020)
Curd cheese	%0.5-1.5	Physicochemical, microbiological, sensory	Patel and Kubavat (2020)
Tofu	%3	Physicochemical, coagulating	Joel et al. (2021)
Local cheese	%1.5	Physicochemical, sensory, microbiological, coagulating	Adesina et al. (2022)
Fresh cheese	%0.05.0.25	Physicochemical, rheological, functional	Wang et al. (2024)

Chen et al. (2020) reported that cashew allergens can be reduced by using a starter culture obtained from quinoa in the production of cashew cheese.

Moringa Oleifera

Moringa oleifera, belonging to the *Moringaceae* family, is a soft tree native to the Himalayan region (Leone et al., 2016). The seeds, roots, leaves, and flowering parts of this tree are suitable for consumption. It is known that its leaves are rich in high protein, antioxidant components, minerals, and ß-carotene (Leone et al., 2015). Moringa seeds attract more scientific attention because they contain high-quality oil and this oil has a wide range of uses for human and animal nutrition (Anwar et al., 2005). In addition, the fact that its seeds have antimicrobial activity (Donli and Dauda, 2003), have antitumor and anti-inflammatory effects (Bharali et al., 2003), and the seed oil has good stability for cooking (Abdulkarim et al., 2005) also expands the area of use of this seed. Moringa seeds are utilized in a variety of cheese production procedures to benefit from their useful properties. *Moringa oleifera* plant seeds are commonly utilized for a variety of applications, including increased productivity and improved milk coagulation in cheese manufacturing (Table 7). It has been shown that *Moringa oleifera* seed oil is more effective at coagulating milk than calf rennet and improves its sensory attributes (Tajalsir et al., 2014). Orhevba and Taiwp (2016) investigated the coagulation process of Wara cheese using several plant sources and concluded that *Moringa oleifera* seed solution was one of the most suited. According to the results of the study examining the use of moringa seed extract in the production of cheeses produced from soy and skimmed cow's milk, it was determined that the seed extract accelerated the coagulation of milk and facilitated the production process (Sánchez-Muñoz et al., 2017). According to the results of the study in which 4 different plant sources (*Moringa oleifera* seed extract, tamarind seed extract, lemon juice and alum) were used as coagulants in the production of tofu cheese, it was determined that *Moringa oleifera* was the plant source with the highest sensory qualities, protein content and coagulation performance (Joel et al., 2021). In another study, 2% *Moringa oleifera* seed powder was mixed with cattle rennet and the coagulation activity was examined (Ismail, 2019).

According to the results of this study, it was determined that the seed powder improved the sensory qualities and coagulation activities of the cheese. The results of the study in which cattle rennet and *Moringa oleifera* seed yeast were used in the production of cheese with buffalo milk are also consistent with these studies (Wang et al., 2024).

According to the findings obtained in this study, it was understood that the cheeses produced with seed rennet had smaller pore sizes, a more uniform conformation, and a denser network structure.

There are also various studies on the effect of moringa seeds on the production efficiency of cheese. In the study where moringa seed extract was used at rates of 0.5%, 1%, 1.5%, and 2% in the production of strained cheese, it was determined that production efficiency increased with the increase in the use rate of moringa seed extract (Mahami et al., 2012). It has also been reported that moringa seed extracts provide an increase in protein and minerals in cheese.In another study, it was determined that the addition of 1.5% *Moringa oleifera* seed extract to cheese increased the protein and fat content of cheese (Adesina et al., 2022). Similarly, it was determined that there was a significant increase in the protein content of cheeses as the use rate increased in cheeses where moringa seed extracts were used at rates of 2%, 3%, and 4% (Salih et al., 2020). According to the results of the study in which different proportions of xantham gum and moringa extract were used in cheese production, it was determined that the amount of protein in the cheese increased (Araújo et al., 2021). The results of a study that added 0.5% and 2.5% *Moringa oleifera* seed powder to Kareish cheese showed that the protein content rose when the seed powder was added (Hatem et al., 2020). The results of this study also showed that the use of seed powder was often associated

with cheeses that had good body and texture, white appearance, long-term storage quality, and general acceptability.

According to the results of the study in which moringa seed powder was used in the production of probiotic curd cheese, it was determined that it contained higher protein compared to the control sample (Patel and Kubavat 2020). In addition to all these, it was determined that cheeses produced with *Moringa oleifera* seed extract and basil leaf extract nanoencapsulated whey protein isolate were effective for the production of functional plant-based cheese. The cheeses prepared in this study were used in the diet of diabetic rats and it was determined that they provided high antioxidant activity as well as an antidiabetic effect (Soliman et al., 2024).

Other Seeds

Apart from the plant seeds mentioned above, there are studies on the use of quince seeds, date seeds, grape seeds, avocado seeds, pumpkin seeds, Lamiaceae, poppy, and hemp seeds for various purposes in cheese production.

Erkaya-Kotan et al. (2023) used quince seed mucilage with thyme oil in kashar cheese coating and determined that quince seed mucilage is a suitable natural alternative for edible coating.

In another study, it was determined that the functional qualities of cheese were increased by using date seeds. In this study, it was determined that it was possible to obtain cheese with high phenolic compounds by adding 1%, 5%, and 10% roasted date seed powder to spreadable cheeses (Darwish et al., 2020). According to a different study that employed date seeds to make cheese, adding date seed fiber at levels of 5%, 10%, 15%, and 20% raised the cheese's fiber content (Alqahtani et al., 2023). It was determined that there was a decrease in hardness, cohesiveness, and springiness in cheese, and the ideal date seed fiber ratio for cheeses was 5% and 10%.

It has been determined that the amount of vitamins and minerals in brine cheeses prepared with the addition of red pepper, coriander seeds, and ß-carotene increases by approximately 2.5 times (Kryuchkova et al., 2020).

It is seen that grape seed powder and seed extract can also be used for various purposes in cheese production. In the results of the study where grape seed powder and seed extract were used to produce functional cheese, it was reported that cheese with the desired sensory qualities could be produced with the use of 0.3% grape seed powder and seed extract and that it provided a rich content in terms of protein, ash, minerals and antioxidant capacity (Elgaml et al., 2018). It is also seen that grape seed oil is used to reduce the unsaturated fat content in cheeses. According to the results of the study where grape seed oil was used at 25%, 50%, and 75% in cheese production, the unsaturated fat content of the cheeses increased and the saturated fat content decreased (Atashzaban et al., 2021).

Avocado seeds can also be included in cheese production processes in various forms. The use of avocado seed powder at a rate of 34 g/kg in spreadable cheese production increased antioxidant capacity, and protein, vitamin, and mineral content (El-Sayed et al., 2023).

Lučan Čolić et al. (2022) determined that the addition of 7.5% pumpkin seed oil is a suitable ratio in terms of sensory qualities in functional cheese paste. According to the results of the study in which 3%, 6%, and 9% pumpkin seed flour were used in the production of low-fat soft cheese, an increase in fat, protein, and fiber content was determined (Azab et al., 2022).

It has been determined that coatings obtained from grapefruit seeds can be an alternative coating method for cheeses (Shin et al., 2012). In this study, red algae films containing 1% grapefruit seed extract were produced and their effect on cheese and pastrami coatings was measured. According to the results of the study, it was determined that this coating increased the antibacterial effect in the foods in question and was effective in reducing *Esherichia coli* and *Listeria monocytogenes* populations.

According to the results of the study in which sheep cheeses were enriched with 1.5% and 2.5% of thyme seed, it was determined that thyme seed oil enriched the omega-3 content and increased cheese productivity (Muñoz-Tébar et al., 2019).

It was determined that the use of aqueous thyme seed extracts at 2%, 4%, and 6% in soft cheese production significantly increased the phenolic components in cheeses and reduced microbial growth (Alsirrag, 2019).

According to the results of the study in which proteins obtained from hemp seeds were used in cheese production at a rate of 1-1.5-2-2.5%, it was determined that the amount of protein and fat content in cheese increased thanks to the seed proteins. It was also determined that these additions increased the production efficiency of cheese (Odintsov et al., 2024). In another study, it was seen that the powder obtained from hemp seeds was added to whey in the production of Skuta cheese (traditional Croatian cheese) (Zandona et al., 2020). In the results of this study, it was determined that hemp seed powders did not have a significant effect on the shelf life of cheese; however, it had a positive effect on mineral and salt content.

The fact that poppy seeds contain components beneficial to human health enables their use in the production of various functional products. For this purpose, it is seen that poppy seeds are used in various ways to enrich the content of cheeses. It has been determined that poppy seeds added to cottage cheese at a rate of 2% improve the mineral content of cheese (Petrova et al., 2023). It has been determined that 200 g of poppy seed cottage cheese meets 31% of the daily calcium need, 35% of the phosphorus need, and 15% of the magnesium need. According to the results of the study in which 20% to 25% poppy seeds were used together with various plant seeds in yogurt and cheese production, it was determined that the nutritional content of yogurt and cheeses increased, and their shelf life was extended (Başlık, 2021). In the results of the study in which 3% blue poppy was used in cream cheese production, it was determined that the nutritional content was enriched in a similar way (Aklale and Güneşer, 2019). In the study in question, it was determined that blue poppy seeds, which are rich in protein and fat, increase the amount of fat and protein in cream cheese and have positive effects on microbiological quality parameters.

Abdul-Rahman (2013) used safflower seed extract as a rennet in the production of white soft cheese. It was found that the cheese produced using safflower seed did not show undesirable bitterness and taste in 14-day storage and was acceptable.

Along with all these, there is also the use of plant seeds together with spices in cheese production. A study in which more than one spice and plant seed (cinnamon stick, clove, thyme, pomegranate peel, and grape seed) was used in cheese production can be given as an example (Shan et al., 2011). According to the results of the study, it was determined that spices and plant seeds had an antibacterial effect against bacteria such as *Listeria monocytogenes*, *Staphylococcus aureus*, and *Salmonella enterica* in cheeses. In addition, it was determined that they prevented lipid peroxidation in cheeses.

Conclusion

Plant seeds are utilized in the production of a variety of foods because of the useful components they contain and the health advantages they provide. This includes dairy items. In recent years, there has been an increased interest in balanced and nutritious diet, which has broadened the applications of plant seeds. There has been a rise in research toward enhancing cheeses with certain plant seeds. Plant seeds are used in cheeses to increase plant protein and unsaturated fat content, increase antioxidant capacity, improve microbiological activity, extend shelf life, enrich nutritional content and/or functional properties, increase production efficiency, and so on. As a result of all of this, it is feasible to conclude that plant seeds represent key examples of innovation in cheese production. Chia, flaxseed, basil, sesame, black cumin, quinoa, and *Moringa oleifera* plant seeds have all been found to be commercially viable in the development of new products. In reality, the references cited in the study show that these plant seeds are economically viable resources in addition to their functional properties.

Declarations

Author Contribution Statement

B.S.: Data collection, investigation, methodology, and writing the original draft

A.E.: Supervision, conceptualization, review and editing

Conflict of Interest

The authors declare no conflict of interest.

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