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Impact of Milk Drying Methods on Its Nutritional Content and Health Benefits

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I. Abstract:

The process of milk drying serves two main purposes which include product shelf-life extension and storage stability improvement and dairy product distribution support. The chosen drying technique determines how well the final product will maintain its nutritional value and functional characteristics. The research assesses how three typical milk drying methods (spray drying , freeze drying , drum drying) affect the stability and bioavailability and physical properties of milk components including proteins and lipids and vitamins and minerals.The review examines experimental results from current times to understand how different processing conditions at various temperatures and moisture levels and oxygen exposure times and drying periods affect nutrient breakdown through protein denaturation and lipid oxidation and vitamin depletion, research investigates how hot temperatures lead to damage of heat-sensitive vitamins and bioactive proteins which results in food quality deterioration and negative impacts on human health, also research investigates how industrial efficiency impacts milk powder nutritional preservation because high thermal processing methods used in milk powder production lead to decreased product quality and performance. The research investigates drying systems which employ oxygen-controlled and vacuum-assisted technologies to maintain food nutrient values while meeting safety and quality requirements. The results demonstrate that proper drying methods and new processing methods need to be developed because they will help maintain both the nutritional value and functional properties of dried milk products.

Key words: Milk powder, Protein Denaturation, Spray Drying Process

II. Introduction:

Milk functions as a nutritious biological substance which mammals produce through their mammary glands to serve as a basic food source for people across the globe. The substance contains 87% water together with its essential macronutrients which include proteins at 3.5% and lactose at 5% and fat between 0.5% and 4% and essential minerals calcium and phosphorus. The nutritional balance in milk makes it a protective food with high

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nutrient density because it contains high levels of calcium which essential for building bones and keeping the skeleton healthy (Woźniak etal.,2022).

Milk provides essential nutrients to the body while containing bioactive substances including conjugated linoleic acid which research links to possible cancer prevention and metabolic wellness advantages. Milk contains insufficient amounts of soluble fiber and phytosterols and long-chain fatty acids but it serves as an excellent delivery system for vital nutrients and bioactive compounds.

The same characteristics which make milk nutritious because of its high-water content and numerous nutrients also make it vulnerable to bacterial contamination (Asante-Poku etal., 2025). The natural weakness of food products creates suitable conditions for harmful bacteria to multiply which leads to fast product deterioration and food poisoning outbreaks when proper food handling techniques are not followed. The solution for milk handling and processing operations needs to defend against microbial contamination while maintaining food quality.

Although it lacks soluble fiber, fatty acids, and phytosterols, milk acts as a transporter of important nutrients and bioactive substances. With its great water content and nutrient-rich makeup, milk is the ideal milieu for several pathogenic bacteria; therefore, foodborne diseases may quickly spread. The only element of the human food (Pereyra-Elías etal.,2022) as the first meal eaten by a young mammal is milk. A range of dried milk products are manufactured because of their advantages in reducing storage and transportation costs. Spray drying is a widely used technique in the pharmaceutical and food industries producing dry powders. Because they are less susceptible to microbial degeneration, their products are of excellent grade. Spray drying is the use of an atomized sprayer to put slurries, which are next dried using high-temperature air. It finds use throughout several industries. One such application in the food industry is milk powder, coffee, and starch manufacturing. Moreover, the creation of spray drying technology presents the chance to make food additives with improved performance and extended shelf life. It helps pharmaceutical businesses create antibiotics, microcapsules. Operator can regulate the process variables such hot air flow rate, input drying temperature, atomizer compress air flow rate, and liquid to atomized rate (Patel etal.,2014) throughout spray drying process.

The process of spray drying makes it difficult to monitor physicochemical changes during intermediate drying stages because it dehydrates numerous droplets at once inside a single drying chamber. The process of accurately studying spray dryer kinetics becomes difficult because researchers cannot observe droplet development in real time. The monitoring of single droplets and continuous shape observation inside industrial spray dryers proves difficult to achieve through in situ methods (Li etal., 2024).

To overcome these constraints, offline single-droplet drying techniques have been extensively employed as complementary experimental approaches for investigating droplet drying behavior. By allowing controlled observation of drying kinetics and morphological transformations under well-defined environmental conditions,

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single-droplet drying provides a simplified yet informative model that approximates convective droplet drying in spray drying systems (Patel etal.,2014).

The research needed different experimental configurations which included surface droplet drying and droplet suspension through syringe or fine wire or glass filament methods and advanced techniques like sonic and electromagnetic levitation (Hyers ,2005; Usui etal., 2023) .

Despite their usefulness, these single-droplet methodologies exhibit inherent limitations when compared with industrial spray drying. The system uses droplets which measure in millimeters instead of microns and it takes minutes to dry the material instead of seconds. The system operates with individual droplets which experience different environmental conditions than what occurs in spray dryers because they lack the multiple interactions between droplets and walls and between droplets and wet particles. The development of kinetic models through single-droplet experiments produces results which differ from the actual measurements obtained in full-scale spray drying operations .

The research investigates the possibility of using single-droplet drying data for industrial spray drying operations through simulation and scaling methods which focus on milk as a fundamental food substance containing proteins and lipids and carbohydrates and vitamins and minerals. Among these, milk proteins especially casein and whey proteins have great biological value and functional qualities, so they are really important in human nutrition. One well used technique for extending shelf life, making transportation easier, and creating several dairy products including powder milk, infant formula, and dairy ingredients is the drying process. But denaturation mostly affects the structural integrity and functional properties of milk proteins when drying methods are employed (Anandharamakrishnan etal., 2007; Kalyankar etal., 2016).

2.Dehydration / Drying of Milk

Powdered milk is a dairy product obtained by dehydrating liquid milk through different drying techniques until it reaches a stable powder form. The process leads to better milk preservation because powdered milk maintains its quality for an extended period than liquid milk and it can be stored at room temperature .

Milk powder production represents a basic industrial operation that can be performed on a large scale. The process operates to extract water from milk through a gentle method which preserves all its natural attributes including color and taste and solubility and nutritional content in controlled sanitary and financial environments. The water content in whole milk reaches 87% but skim milk contains 91% water according to composition analysis.

Water is removed in milk powder manufacture by boiling the milk under decreased pressure at low temperature in a process known as evaporation. One hundred liters of whole milk will yield roughly 13 kg of whole milk powder (WMP) or 9 kg of skim milk powder (SMP).

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Three types of dryers are used in the production of dried milk products spray dryers, drum dryers, and freeze drying:

The dairy sector uses several drying methods, with spray drying being the most common. Other techniques include freeze-drying, drum drying, and vacuum drying. All these methods evaporate water using specific pressures, temperatures, and exposure times. Though vital for milk preservation, these processes occasionally change its structure.

Spray drying, the most common commercial technique, turns milk into powder by atomizing it into hot air. Freeze-drying, or lyophilization, freezes milk and then pulls the water out through sublimation at low pressure. This helps keep more nutrients. Drum drying is another method in which milk is spread over heated drums, forming thin films that dry rapidly. Drying milk is an excellent process of transforming fresh milk into powdered form. Powdered milk remains edible for a long time and requires reduced storage space and can be transported easily. Milk can be dried using various techniques. Each of them operates differently and has its benefits and applications. The basic ones are spray drying and drum drying, freeze drying and roller drying.

1-*Spray Drying*

Evaporation usually preconcentrates the liquid milk to lower the water content at an affordable level. The concentrate is next sprayed or mist into a tower or chamber of heated air as a delicate spray. The minute droplets flash off their moisture, become little particles, and sink to the bottom of the tower as they make close contact with the hot air. Spray drying offers low heat and quick time combination, which results in a product of higher quality.

Most milk powder is made by spray drying. Milk is initially pasteurized in this procedure before being sprayed into microscopic particles using a spray nozzle. Typically between 150°C and 200°C, these droplets are fed into a hot air chamber where high temperature causes rapid evaporation. Virtually immediately, the moisture vanishes to leave behind small milk powder particles caught in either a cyclone or a bag filter. Spray drying has several benefits: continuous operation, great efficiency, and the capacity to generate a free-flowing powder with consistent particle size. Large-scale commercial manufacturing benefits from it (Romo etal., 2024).

Spray Drying Process

Among the most often employed milk drying methods is spray drying, much used in the dairy industry to create powdered milk. Spray drying is a method of quickly extracting moisture by atomizing the liquid milk into small

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droplets and exposing them to hot air. Although this technique is effective and preserves many nutrients because of its fast process, high temperatures can degrade some heat-sensitive nutrients, particularly particular vitamins such as vitamin C and some B vitamins. Although proteins and lipids are rather stable, extended exposure to heat can result in Maillard reactions, which can change amino acids and lower nutritional value (Li etal., 2024).

A- ***Separation***

The conventional process of milk powder manufacture starts with raw milk delivered to the dairy plant, where it is pasteurized and then separated into skim milk and cream by means of a centrifugal cream separator. When whole milk powder is required, a controlled proportion of the cream is recombined with the skim milk to obtain a standardized fat level, typically ranging from 26% to 30% in the final powder. Any excess cream produced during this step is directed toward the manufacture of butter or anhydrous milk fat.

B- Preheating

The conventional process of milk powder manufacture starts with raw milk received at the dairy plant, where it is pasteurized and then centrifugally separated into skim milk and cream using a centrifugal cream separator. The production of WMP requires skim milk to receive back some of its cream which results in milk with a fixed fat percentage that ends up as 26–30 percent in the final powder product. Excess cream is directed toward butter production or anhydrous milk fat manufacture processes.

C-*Evaporation*

The process of milk concentration involves vacuum-based evaporation which removes water at temperatures below 100 °C to create a falling film that coats the inner walls of vertical tubes. During spray drying, the concentrated milk leaving the evaporator is converted into fine droplets. The process of atomization occurs through two methods which include rotating disk atomizers and high-pressure nozzle systems that operate inside a big drying chamber which uses hot air at 200 °C temperatures. Inside the spray drying chamber, the overall residence time remains very short, typically ranging between 20 and 60 seconds.

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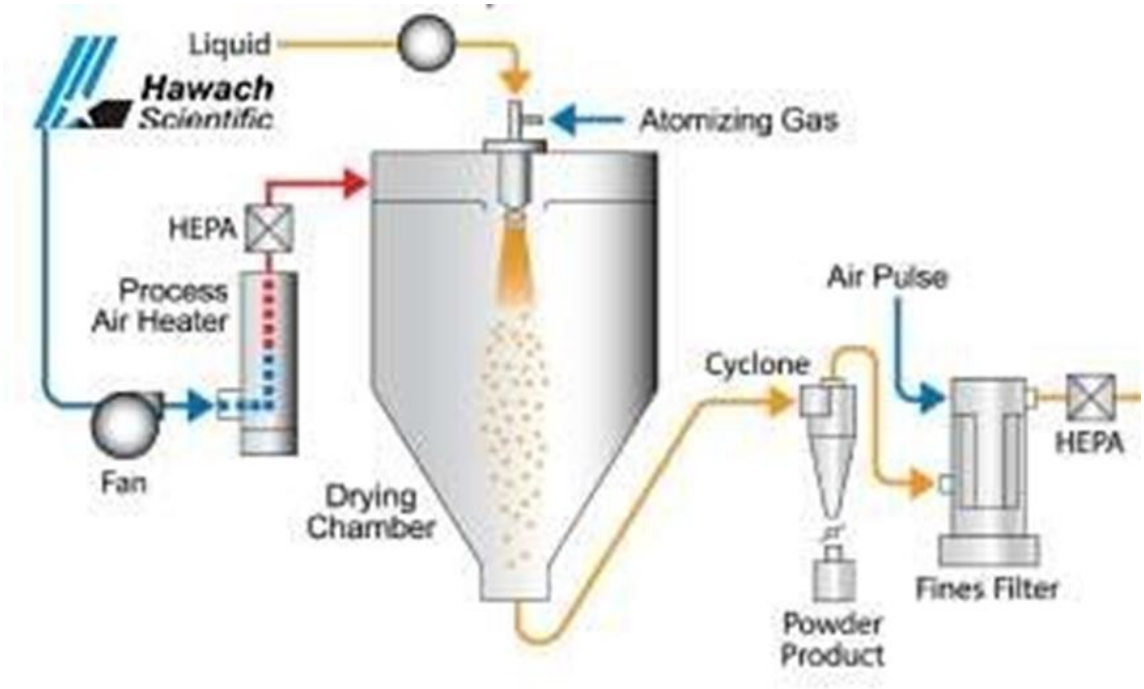

Fig.1 Milk Spry drying System

Main advantages of spray drying:

1-Very short drying time

2-Large scale continuous production

3-Low labor costs

4-Relatively simple operation and maintenance (Rawat eta., 2020)

Disadvantages:

1-Much heat is lost in discharge gates

2-Higher volatile losses

2-*Drum Drying*

Direct heat on heated drums characterizes drying methods including roller drying and drum drying. Particularly of heat-sensitive vitamins and some proteins, these processes can result in major nutrient loss. Maillard browning which not only alters the color and flavor but also lowers the nutritional quality of the milk powder can be brought on by the elevated temperatures and extended exposure durations.

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With the hot surface of turning rollers or drums, a layer of concentrated milk is directly touched during roller drying. Inside the drum body of the drum dryer is heated by steam. Milk is spread as a thin film over the surface of a heated rotating drum or cylinder in drum drying. As the drum turns via a heating chamber, the milk's moisture evaporates rapidly. The dried film is then scraped from the drum surface to produce powder. Although drum drying is simple and inexpensive, the resulting particles are larger and coarser than those from spray drying. It is mostly used for producing milk powders with specific characteristics, such as for use in baking or as ingredients in other products.

The main characteristics of a drum drying system are as follows:

The system consists of one or more drums which rotate at a slow pace while their diameters span from 0.6 to 3 meters and their lengths extend from 0.6 to 4 meters. 1- The system operates at a rotational speed which produces 1 to 10 revolutions per minute .

2 -Steam is supplied internally to provide thermal energy for heating the drum surface .

3 -Systems may be configured as single-drum, double-drum, or twin-drum units .

4 -Feed application is achieved either by dipping or by spraying the product onto the drum surface .

5 -A scraper or doctor blade is used to remove the dried product from the drum .

6 -The drums can be enclosed within a vacuum chamber when required .

7 -The drying process occurs at temperatures above 100 °C during a 30–60 second residence period .

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8 -The process of browning reactions and burnt flavors and protein denaturation occurs when food products experience elevated temperatures.

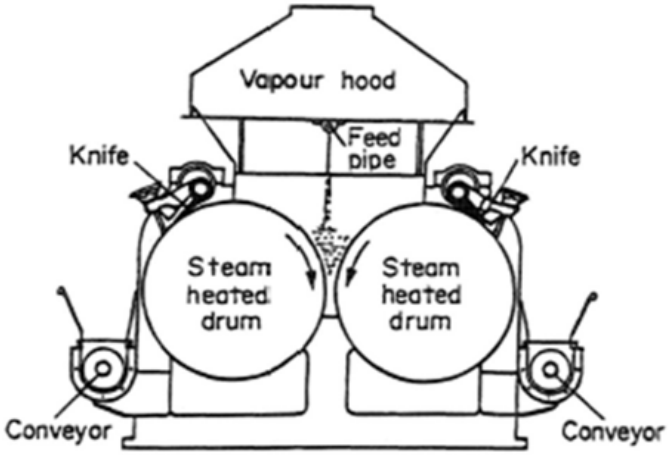

Fig 2. Milk Drum Drying System

3-*Freeze Drying*:

Freeze drying of milk utilizes a process referred to as lyophilization, in which the product is gradually frozen and subsequently subjected to a high vacuum that removes water directly in the form of vapor. The vapor is captured on a condenser located beneath the freezing chamber, where it re-solidifies as ice and is subsequently removed.

A slow rise in temperature extracts any remaining 'bound' humidity from the item. This technique keeps the item's physical makeup intact so that it is suitable for storage or shipping. The most nutrient-preserving process is thought to be freeze drying because it works at low temperatures and lowers thermal stress. As a result of spray drying, vitamin C and B-vitamins are better held. Still, oxidative processes during processing or storage can produce some little losses, particularly if exposure to light or oxygen is not properly regulated.

Lyophilization is a dehydration technique in which water is removed from a product after freezing by applying a vacuum, allowing ice to transition directly from the solid state to vapor without passing through a liquid phase.

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Freeze drying lyophilization involves freezing milk then lowering the surrounding pressure to enable the frozen water to sublimate straight from solid to vapor. Freeze-dried milk is nutritionally equivalent to fresh milk as its protein structure, minerals, and vitamins stay mostly intact. However, the process is more expensive and less often utilized for mass production because it happens at low temperatures, hence reducing nutrient deterioration (Ibrahim eta., 2015).

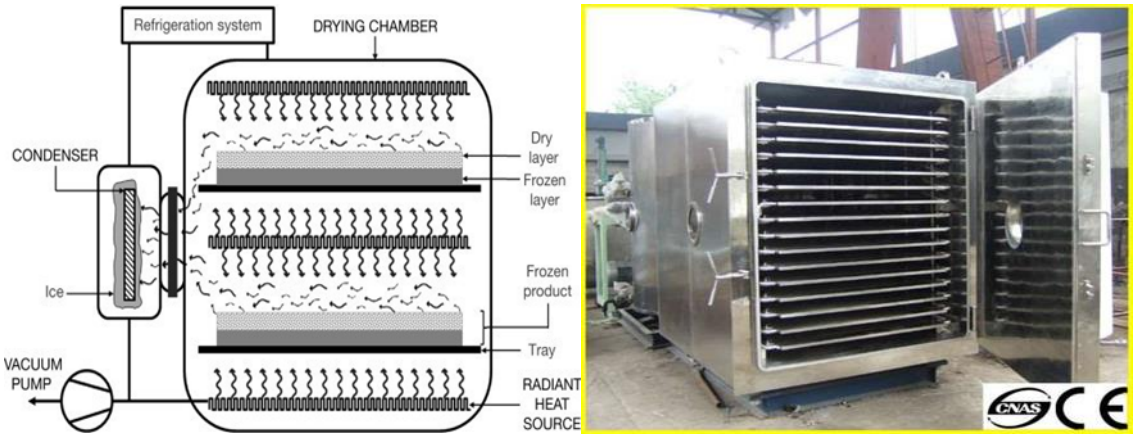

Fig 3. Milk Freeze Drying system

The process of freeze drying is divided into three steps:

1 -The first requirement demands that the shelf temperature needs to reach −5 °C before maintaining this temperature at −5 °C for twenty minutes .

2 -The shelf temperature drops to −50 °C at a fast rate after this point. The sample temperature needs to reach −45 °C before staying at that temperature for one hour to start the primary drying stage .

3 -The shelf temperature reaches 5 °C before staying at this level for five hours before the system raises it to 35 °C for four more hours to finish the freeze-drying operation (Alibekova etal., 2025).

***Advantages of Freeze-Drying Dairy Products*:**

The freeze-drying process enables businesses to preserve solid and liquid products through a method which protects their original structure so fresh products retain their natural appearance and size and flavor and nutritional value and texture .The storage requirements of freeze-dried dairy products include no need for refrigeration or chemical preservatives because they can be eaten immediately or easily rehydrated for consumption at any time.

Disadvantages:

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1-Volatile compounds may be removed by high vacuum

2-Long time needed (Lực etal.,2024).

3-energy consumption

Effects of Drying Methods on Vitamins:

Vitamins are essential nutrients that perform specific functions in the body. Milk's vitamins include water-soluble vitamins like B-complex and vitamin C as well as fat-soluble vitamins such as A, D, E, and K. Vitamins are sensitive to destruction, especially with a high-temperature process like spray drying and drum drying due to heat, oxidation and contact with oxygen.

The drying process can damage the most heat-sensitive vitamins, especially vitamin C and some B-vitamins like B1, B2 and B6. An instance can be vitamin C which may undergo oxidation and thermal degradation in the process. Like other vitamins, B- vitamins can also be damaged by heat as well as oxygen. Thus, the final powder loses some of its nutritional value (Erenturk etal., 2005). The degree of loss of vitamins depends on temperature, duration of drying, exposure to oxygen. Vitamins in milk can be classified into two groups given below: water-soluble vitamins B-complex vitamins and vitamin C and fat-soluble vitamins (A, D, E, and K). These vitamins are heat-sensitive and may be destroyed due to oxygen, light, and moisture. These are essential when drying. The most important ways that vitamins break down while the milk is dried are by heat, oxidation and the Maillard reaction. Thermolabile vitamins break down faster with heat. Crooxidative damage takes place following oxygen exposure. Light may cause photoxidation of vitamin A and carotenoid components. Residual moisture may facilitate hydrolytic degradation.

Mechanisms of vitamin loss during milk drying

Thermal degradation happens when the inlet air temperature (spray drying, e.g. >160°C) is too high because of which a substantial quantity of heat-sensitive vitamins (B1, B12, C, Folic Acid) is lost and there is denaturation of milk proteins. Vitamin A, D3, E and C undergo destruction by oxidation when exposed to oxygen and sometimes light during processing and storage. The reaction which takes place with heating of lactose and protein on drying and storage result in browning (Maillard reaction) which affects availability of nutrients and stability of vitamins B1 and B2. Some photosensitive vitamins like B2 (Riboflavin) and B6 degrades due to light during processing or when packaged in transparent packs. When unsaturated fats oxidize in whole milk powders, secondary reactions will degrade fat soluble vitamins (D3) and form cholesterol oxidation products (COPs) (whether that's bad for you is a different discussion). High inlet air temperature causes the thermal degradation of a substance Strategies to Minimize Vitamin Loss (Sharma eta., 2002).

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Various methods are used to maintain the vitamins present during drying. Inhibition of oxidation in the substrate, controlled by use of antioxidants, is called as protective agent. Techniques to microencapsulate can protect sensitive vitamins during processing. By decreasing temperature, shortening exposure time, and controlling oxygen levels, it is possible to reduce the loss of nutrients. Furthermore, using oxygen-proof materials as well as packing in controlled conditions can stabilize vitamins.

Protein Denaturation During Drying:

The production of milk powder and dairy products requires milk drying as an essential process which provides benefits including longer product shelf life and smaller storage needs and better transportation capabilities. The drying process affects milk protein structure and function because it causes protein denaturation to occur. The process of protein denaturation involves structural changes to proteins which result in their native conformational structure becoming unfolded. The drying process which includes spray drying at high temperatures exposes proteins to thermal stress and mechanical shear and possible oxidative environments. The system will experience permanent changes because of these factors which cause proteins to aggregate and coagulate while their solubility decreases. The process of denaturation occurs because it breaks the hydrogen bonds and ionic bonds and hydrophobic interactions which hold proteins in their native structure. The modifications in protein structure result in changes to tertiary and quaternary structures which produce different functional properties including solubility and emulsifying ability and foaming behavior and gelation capacity (C˘urlej etal., 2022).

Protein alterations during spray drying become more pronounced at elevated temperatures and are strongly dependent on the inlet air temperature. The research shows that whey proteins show low thermal denaturation during spray drying because IgG proteins stay intact while serum albumin proteins experience between 3% to 7% structural changes (Ogbodo eta., 2025). Milk proteins are primarily classified into caseins and whey proteins. The thermal stability of caseins exists at a higher level than whey proteins which include β-lactoglobulin and α-lactalbumin because these proteins denature when exposed to heat. The high temperatures which occur during spray drying and drum drying operations cause whey proteins to undergo denaturation. The process of protein denaturation occurs through the breakdown of secondary and tertiary protein structures because hydrogen bonds and disulfide linkages and hydrophobic interactions get cleaved. The drying process causes protein denaturation which affects both the operational properties and dietary value of milk. The functional properties of denatured proteins will change their ability to dissolve in solutions and their capacity to create emulsions and their ability to produce foam.

The decreased solubility of denatured whey proteins results in poor reconstitution properties which causes dairy product textures to become different. The controlled denaturation process offers two benefits because it protects proteins from heat damage and enables proteins to create gel-like structures. The denaturation process does not decrease protein amounts in laboratory research but it affects protein digestion because enzymes break down

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denatured proteins at different rates which impacts nutrient absorption in the body. High thermal exposure leads to Maillard reactions which cause food browning but also breaks down essential amino acids including lysine. The optimization of drying conditions through temperature and airflow rate control and product residence time management helps to minimize these negative effects. The process of spray drying becomes more effective when operators use lower inlet air temperatures because this method protects proteins from denaturation while allowing the correct amount of moisture to evaporate. Freeze drying represents an efficient method for preserving milk protein native structures although it requires higher production expenses.

The process of protein denaturation does not change the amount of protein present but it does affect how well proteins can be digested. The degree of structural changes in denatured proteins determines their exposure to digestive enzymes in the human gastrointestinal system which affects their ability to absorb nutrients. The process of heat treatment beyond recommended levels will trigger more Maillard reactions which results in food browning while it breaks down essential amino acids including lysine. Manufacturers make ongoing changes to their drying process parameters which include temperature settings and airflow rates and thermal exposure time to reduce these negative impacts .

The spray drying process uses lower air temperatures to protect proteins from denaturation while achieving proper dehydration results. Freeze drying stands as the preferred method for preserving protein structure although it requires more expensive operations. Milk proteins serve as essential ingredients in food production because they perform multiple functional duties yet their degradation process affects their solubility properties which matter for beverage and infant formula production. The emulsification and foaming properties of products experience changes because of denaturation which affects their texture and stability. The denaturation process of whey proteins leads to reduced solubility but this change improves their gelation properties which benefits yogurt and cheese production (Carter etal., 2017). The heat-based drying process of proteins maintains their nutritional value but it damages their functional characteristics and produces extensive protein aggregation which creates difficulties for protein digestion.

***Impact of Drying Processes on Nutritional Composition of milk**:*

The nutritional properties of milk are greatly influenced by the way it is dried, which has an impact on its quality and shelf life. Proteins, fats and carbohydrates (mainly lactoses), as well as vitamins and minerals are also found in milk. Various factors such as drying process, temperature and time (as opposed to organic matter), and environmental influence can affect these nutrients. Proteins may lose their amino acid content due to high temperatures, which can alter their functional properties.

Vitamins: Some vitamins, especially the heat- Some vitamins, like vitamin C and certain B vitamins (like B1, B6, and B12), can lose their effectiveness when they're dried out .

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Lipids: Under high heat, lipids can oxidize, therefore reducing vital fatty acids in addition to causing rancidity.

Minerals: Although minerals are usually steady, their contacts with other nutrients or oxidation byproducts can nonetheless affect them indirectly.

Disadvantage of milk Drying Technologies on human health:

Regarding drying techniques, extended heat exposure can cause some undesirable substances to form. Consider, for example, high-temperature methods such frying or roasting; they might start the Maillard reaction, which produces acrylamide and advanced glycation end-products (AGEs).

These compounds have been associated with oxidative stress, inflammatory responses, and an elevated risk of chronic diseases, including cancer and cardiovascular disorders. Accordingly, improper drying practices may introduce potential health risks rather than mitigating them. A major concern related to drying technologies is the loss of heat-sensitive nutrients. Exposure to elevated temperatures during drying can degrade vitamins such as vitamin C and B-complex vitamins, as well as certain phytochemicals. For example, sun drying or hot-air drying conducted at high temperatures may result in substantial nutrient depletion.

When evaluating drying techniques, several critical factors must be considered. High-temperature methods, particularly spray drying, can lead to the degradation of sensitive nutrients, including essential vitamins and proteins, thereby reducing the overall nutritional quality of milk. Moreover, excessive thermal treatment may promote the formation of potentially harmful compounds, such as acrylamide and advanced glycation end-products (AGEs), which have been linked to adverse health outcomes. Another significant concern is microbial contamination. Inadequate drying or improper storage conditions may facilitate the growth of bacteria, molds, or the production of mycotoxins, increasing the risk of foodborne illness upon consumption.

Additionally, certain drying processes may alter the allergenic properties of milk proteins, potentially intensifying allergic reactions in susceptible individuals. The use of preservatives or anti-caking agents in some drying methods may also provoke unfavorable responses in sensitive consumers. Furthermore, heat-induced structural modifications of proteins can influence their bioavailability and digestibility, thereby affecting overall nutritional intake and utilization (Rawat eta., 2020).

Factors Affecting Nutritional during milk drying:

The drying process affects nutrient stability through various factors which influence the process.

1 -The process of temperature elevation causes nutrient degradation because heat-sensitive vitamins and enzymes become unstable when exposed to high temperatures .

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2-The duration of drying time stands as a vital element because extended heat exposure leads to higher chances of nutrient degradation .

3 -The presence of oxygen promotes oxidative reactions, which may result in lipid peroxidation and negatively affect fats as well as fat-soluble vitamins .

4-The control of residual moisture needs the same level of importance as moisture content because it prevents microbial growth and enzyme activation which leads to nutrient deterioration following drying .

5-Water-soluble vitamins become unstable when exposed to heat and oxygen because vitamin C and B vitamins (thiamine B1 and riboflavin B2 and pyridoxine B6) break down more easily. Because it processes most of these nutrients quickly, spray drying is ideal for preserving them; however, methods like drum and roller drying can result in considerable losses. While high heat can denature proteins which impacts their solubility and digestibility generally, they are stable throughout drying.

6-Fats are rather resilient, yet at high temperatures or in the presence of oxygen they may oxidize and become rancid. On the other hand, minerals are not heat-sensitive thus they are stable across all drying techniques.

***Dried milk*:** Often considered a dairy product, milk powder is produced by freezing or spray drying liquid milk to remove the water content. Most of the nutritional advantages of fresh milk are preserved in this focused, shelf-stable powder.

Health Benefits of Dried Milk

1-Nutrient Density:

Most of the nutrients present in fresh milk are kept in dry milk, so it's a concentrated source of vital vitamins and minerals. It is high in calcium, especially in the elderly and children, which is necessary for strong bone growth and preservation. Dried milk also has great levels of vitamin D, which helps calcium uptake and promotes strong bones. Dried milk serves as a protein-rich food source which contains vital nutrients for body development and immune system operation and muscle tissue healing.

2-Shelf Life and Convenience:

Dried milk provides users with its ability to stay fresh for an extended period of time. Dried milk maintains its stability for months or years when stored properly but fresh milk becomes spoiled within a short period of time. The food option holds special value because it remains safe to eat in areas without refrigeration and during times of emergency and crisis. The product serves as a basic food ingredient because it enables multiple cooking

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applications in food preparation and baking and drink preparation while delivering consistent results (Wang,2024).

3-Cost-Effectiveness:

The price of dried milk stays cheaper than fresh milk throughout different parts of the world because fresh milk needs refrigeration which most communities do not have. The affordable price of this product enables more people to access it which helps solve malnutrition problems in developing nations .

4-Potential for Fortification

The nutritional value of dried milk becomes better through manufacturer addition of vitamins A and C and iron to the product. The population benefits most from this fortification approach because it helps protect people who develop micronutrient deficiencies .

Potential Risks and Concerns Associated with Dried Milk

1-Nutrient Loss During Processing

The drying process of powdered milk preserves most of its nutritional content but it might lose some of its vitamin content. The processing of food products makes vitamin C and particular B-complex vitamins unstable until manufacturers add fortification to restore their essential compounds.

2-Shelf Life and Convenience

One of the best things about dried milk is how long it lasts. Fresh milk goes bad , but dried milk can stay good for months or even years if you store it right. This makes it a key food option in areas without much refrigeration or during emergencies. It's also great for cooking baking, and making drinks, which makes it even more useful as a reliable food supplement.

3-Cost-Effectiveness

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In regions without access to refrigeration or dairy farming, dried milk is cheaper than fresh milk. The cost-efficiency not only solves the refrigeration problem but also increases the likelihood of addressing malnutrition, especially of milk nutrients, in poorer countries.

4-Potential for Fortification

To enhance the nutritional value of dried milk, manufacturers add vitamins A and C and iron. Such products may be especially beneficial for nutritionally vulnerable populations.

5-Nutrient Loss During Processing

Although most nutrients are preserved in dried milk, some vitamins especially the heat-sensitive ones, such as Vitamin C and some B Vitamins can be lost during the drying process. Unless the dried milk is fortified properly, the potential health benefits may be diminished.

6-Presence of Additives and Preservatives

Some commercially sold evaporated and milk powders may contain food additives, emulsifiers, or preservatives to improve shelf life, mouthfeel, or flavor. Unfortunately, some people may be sensitive or allergic to some food additives. Hence, it is important for consumers to read ingredient statements and choose food products containing fewer and/or more naturally occurring food ingredients.

7-Potential for Contamination

In the same way to every other processed food item, dried milk is also prone to the dangers of underdeveloped production processes, Poor production techniques can result in dangerous microbial contamination, including the likes of Salmonella and E. coli. and so the importance of correct processing, pasteurization, and the safe storage of dried milk.

8-Allergen Risks

Milk powder contains protein from dairy which, along with other products from a cow, can cause an allergy in some people. If you are lactose intolerant and/or have a milk protein allergy, you are best off not consuming any dried milk products as you would potentially subject yourself to a milk reaction. If you suffer from any of these issues, you can be sensitive to a milk protein and its health effects can include digestive issues, an allergic response, and in some cases, a more serious medical condition.

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9-High Sodium Content in Some Variants

Specialty dried milk products may contain added flavorings or salt. It is good to note that over-consuming sodium is linked to increased risks of hypertension and cardiovascular disease.

10-Potential for Overconsumption and Caloric Intake

Dried milk is quite calorie-dense, so if you indulge a bit too much, it could lead to weight gain especially if you're not keeping track of your overall caloric intake.

The current eating habits which focus on processed foods require special attention to these dietary elements. The existing environment does not prevent dried milk from providing essential nutritional value together with long storage capabilities and affordable price which makes it an important food choice for people who live in areas with limited resources. The consumption of this product comes with several possible negative aspects. The process of food production requires monitoring of three main concerns which include nutrient loss during processing and product contamination and food allergens and added substances. People should choose dried milk products with high quality that need less processing and they should check labels thoroughly while using these products as part of their complete and varied diet. People who have allergies or lactose intolerance need to take special care because they should select non-dairy alternatives whenever they need to. Overall, when used thoughtfully, dried milk can be a nutritious and convenient addition to a healthy diet, but it's essential to be aware of its limitations and risks for safe consumption.

Conclusion:

The drying method which milk processors use determines how well protein structures in milk will survive while maintaining their functional properties. The drying process serves as an essential step for product stability and storage efficiency and handling convenience but requires precise control of processing conditions to prevent protein modification damage. The combination of new technological developments with process enhancement methods has resulted in quantifiable quality enhancements for milk powder which preserves its nutritional elements and functional characteristics. The research will concentrate on building soft drying techniques and developing protective compounds which prevent protein breakdown during food dehydration processes .

Milk stands as a nutritious food which contains all necessary vitamins and minerals and proteins that people need for their health. The natural tendency of this product to spoil quickly requires different drying techniques which help extend its storage duration and make it easier to transport. The drying process provides several benefits to food producers yet it causes major vitamin losses which reduce the nutritional content of processed foods. The

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research evaluates how different milk drying methods affect vitamin preservation through an analysis of degradation processes and methods which minimize nutrient degradation during manufacturing operations.

References:

Alibekova,R.S. , Aitbayevaa,A.Z., Khamitovaa , B.M., Azimova,A.M., Sulaimanb,A., Siti MazlinaMustapa Kamalb,S.M.M. and Taip,F,S.(2025). Effects of maltodextrin in freeze drying on the physical and functional properties of different type of milk powder. Cogent Food & Agriculture, 11(1),2473540. https://doi.org/10.1080/23311932.2025.2473540.

Anandharamakrishnan, C., Riellya, C.D., Stapleya, A.G.F.(2007). Effects of process variables on the denaturation of whey proteins during spray drying. Drying Technology, 25(5),799–807.

Asante-Poku, A., Afrifa Yamoah, J.A., Ahiabor, P., Christian, B., Vida, A., Salifu, S. and Mogre, J.W.S. (2025) .Microbial Safety of Milk from Small- Scale Dairy Farms in Northern Ghana. Advances in Microbiology, 15,163-180. https://doi.org/10.4236/aim.2025.154013.

Cˇurlej, J., Zajác,P., Cˇapla ,J., Golian,J., Benešová , L., Partika, Alexander Fehér ,A., Jakabová,S.(2022). The Effect of Heat Treatment on Cow's Milk Protein Profiles. Foods, 11, 1023. https://doi.org/10.3390/ foods11071023

Carter,B., Patel,H., Barbano,D.M., Drake,M.A.(2017). The effect of spray drying on the difference in flavor and functional properties of liquid and dried whey proteins, milk proteins and micellar casein concentrates. In book: Handbook of Milk Production. Quality and Nutrition J. Dairy Sci., 101,3900–3909. https://doi.org/10.3168/jds.2017-13780,

Hyers, R.W.(2005). Fluid flow effects in levitated droplets. Meas. Sci. Technol. 16,394

Ibrahim, A. H. and Khalifa, S. A.(2015). Effect of freeze-drying on camel's milk nutritional properties. International Food Research Journal, 22(4),1438-1445 .

Kalyankar S.D., Deshmukh M.A., Chopde S.S., Khedkar C.D., Lule V.K. and Deosarkar S.S. (2016). Milk Powder. In: Caballero, B., Finglas, P., and Toldrá, F. (eds.) The Encyclopedia of Food and Health. 3 ,724- 728. Oxford: Academic Press.

Li, X., Al-Asady, R.B., Sanders, C. Salman.A.D. (2024). Comparing different single milk droplet drying process with spray drying process. Chemical Engineering Research and Design, 205 (2024) ,47–56. https://doi.org/10.1016/j.cherd.2024.03.022

Lực,N.V., Hiếu,T.V. and Hoàng Thái Hà,H.T.(2024). Convection freeze-drying on squid: Principles, advantages and disadvantages .International Journal of Science and Research Archive. 11(01), 1281–1285. DOI: https://doi.org/10.30574/ijsra.20 .

Erenturk,S.,

ISSN Onlin:2708-9347, ISSN Print: 2708-9339 Volume 14, Issue 2 (2025) PP 351-369

https://iasj.rdd.edu.iq/journals/journal/issue/18682 https://doi.org/10.54174/utjagr.v13i1.323

Gulobogglu,M.S.,Gultekia,S.(2005). The effects of cutting and drying medium on the vitamin C content of rosehip during drying. Journal of Food Engineering, 68(4),513-518. DOI: 10.1016/j.jfoodeng.2004.07.012.

Ogbodo,U.F.,Adereti, A.O.(2025). Chapter 52 - Biological hazards associated with milk and milk processing and its impacts on consumer health. 619-625. DOI: 10.1016/B978-0-443-24820-7.00021-3.

Patel, A.D., Agrawal, A., Dave, R.H. (2014). Investigation of the effects of process variables on derived properties of spray dried solid-dispersions using polymer based response surface model and ensemble artificial neural network models. Eur. J. Pharm. Biopharm, 86, 404–417.

Pereyra-Elías, R., Quigley, M.A., Carson, C. (2022). To what extent does confounding explain the association between breastfeeding duration and cognitive development up to age 14? Findings from the UK Millennium Cohort Study. PLoS One 17, e0267326.

Rawat ,K., Kumari,A., Kumar,R., Partibha.(2020). Spray Dried Fermented Milk Products. Int.J.Curr.Microbiol.App.Sci ,9(7), 1293-1299. https://doi.org/10.20546/ijcmas.2020.907.148.

Romo, M., Chutani, D., Fartdinov, D., Panthi, R.R., Vahedikia N., Castellari, M., Felipe, X., Murphy, E.G.(2024). Pulse Spray Drying for Bovine Skimmed Milk Powder Production .Foods, 13(6), 869. https://doi.org_foods130608610.3390

Sharma,R . and LAL,D.(2002). Stability of Different water-soluble vitamins During preparation and subsequent storage of spray Dried Buffalo skim milk powder.J.Food Sci.Technol,39(4),439-441

Usui, T., Shiratori, S., Tanimoto, K., Ozawa, S., Ishikawa, T., Suzuki, S., Nagano, H., Kenjiro, K.(2023). Surrogate models for the magnitude of convection in droplets levitated through EML, ADL, and ESL methods. Int. J. Microgravity Sci. Appl, 40, 400302

Wang, Z.(2024). The Economic Benefits of Milk Powder and its Significance . J Adv Dairy Res, 12 (1):1000654.

Woźniak, D., Cichy,W., Dobrzyńska,M. (2022). Reasonableness of enriching cow's milk with vitamins and minerals. foods, 11(8) ,1079. https://doi. org/10.3390/foods11081079