

Health Benefits of Dairy Products; Steps towards Improvement of Dairy Safety and Industrialization in Developing Countries: A Review

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Abstract: A Dairy product is a type of food obtained from milk of mammals (cow, sheep, goat and camel). Common dairy products include cheese, yogurt, and butter. Nutritional content of dairy include protein, vitamins, omega-3 fatty acid, calcium, potassium, phosphorus and magnesium. Dairy products are a quintessential constituent of proposed good nutrition in poor economies, and are an intrinsic aspect of milk production, preparation, and consumption. The different dairy products common to developing countries are *Kariesh* (Egypt), *Ayib* (Ethiopia), *Gibna* (Sudan), *Nono* (Nigeria), *Wara* (Nigeria) and *Ghee* (India). Microorganisms involved in fermentation of milk include Lactic acid bacteria (*Enterococcus*, *Lactobacillus*, *Lactococcus*, *Oenococcus*, *Streptococcus*, *Vagococcus*, and *Weissella*). Natural antimicrobial systems in milk, use of antimicrobial additives (using plant extracts or plant parts such as *Olea europea* (root) *Lippia javanica* (stem), or *Olkingiri* (stem) and heating, conventional production techniques such as fermentation (transform lactose (milk sugar) to lactic acid), and other variables all result in the processing and safeness of dairy products in underdeveloped regions. Pathogens of public health concern in the dairy products include *Bacillus subtilis*, *Brucella abortus*, *Coxiella burnettii*, *Escherichia coli*, *Listeria monocytogenes*, *Mycobacterium bovis*, and *Staphylococcus aureus* still persist in these developing countries. Weight management, improved gut health, digestion, healthy bone, muscle mass are health benefits of dairy consumption. Dairy farmers would require updated knowledge and basic training to prevent contamination of dairy such as hazard analysis and critical control points (HACCP) design, implementation of good hygienic practices (GHPs) and good agricultural practices (GAP).

Key word: *Nono*, *Wara*, Calcium, Food safety.

INTRODUCTION

Milk is highly nutritious, it comprises sugar present as lactose, it also contains prebiotics, probiotics, proteins, essential amino acids, fats, as well as different minerals and vitamins. Milk has played an important role in human development over the thousands of years. The positive impact of dairy products consumption include healthy gastrointestinal microbiome, improved cardiovascular health and a strong bone mass (Barnabas and others 2014; Omola et al., 2020).

Products of the industrial dairy sector include evaporated milk, powdered milk, cheese, butter, yogurt and ice cream (Omola et al., 2020). The different indigenous dairy products common to developing countries are *Manshanu* (Nigeria), *Kariesh* (Egypt), *Ayib* (Ethiopia), *Kindrimo* (Nigeria), *Gibna* (Sudan), *Nono* (Nigeria), *Meekiri* (Sri Lanka), *Sary mai* (Kazakhstan), *Wara* (Nigeria), *Ghee* (India) and *Jocoqui* (Mexico) (Omola and others 2020). Natural controlled

fermentation is used to make products such as *woagashi* in Benin, *bouhezza* in Algeria, *amasi* in Zimbabwe, *tchoukou* in Niger, *amabere amaruranu* in Kenya, *kivuguto* in Rwanda, *masse* in Mozambique, *omashikwa* in Namibia, *pendidam* in Cameroun, *sussa* in Somalia, *urubu* in Burundi, *dahi* in the Indian subcontinent, *laban* in Syria, and other soured milk in southern and eastern Africa (Addis and others 2016).

Lactic acid bacteria (LAB), which are found in the indigenous micro flora of raw milk and are primary ingredients of starter cultures being used for fermentation, enhance the taste and aroma of fermented cheese products while preventing food spoilage bacteria by developing growth-inhibiting compounds and vast quantities of lactic acid. Starter cultures play different roles in dairy production, including acid production from lactose, spoilage and pathogenic microorganism inhibition, dairy-keeping quality improvement, and active and passive contributions to organoleptic properties.

The quantity and diversity of microorganisms in the starter are determined by the technological process, particularly the use of natural whey starters (Omola *et al.*, 2020). Food safety, production, handling, preservation, and storage all rely on microbiology. The production of dairy products is partly dependent on selective growth of microbes, such characteristics also

can permit the replication of undesirable pathogens. Microorganisms from the farm, feed, milking, and processing equipment eventually lead to contamination of milk. Poor hygiene, unprofessional handling of milk, and animal health issues lead to lowered quality, reduced yield, and erratic breakouts of dairy-related disease (Rakhmanova and others 2018).



Figure 1: Vendors of Dairy products as commonly seen in local markets in Africa
Source: (Benkerroum 2013)

Under-Developed Countries

Countries are regarded as developing and developed focusing on their GDP or GNI per capita, degree of industrial growth, overall living standards, and volume of technology and infrastructure (International Monetary Fund 2020). The United Nations (UN) defines a country's development status as a projection of its "basic economic nation circumstances." (United Nations 2020). Africa, Asia, Latin America, and Australia/Oceania are all examples of developing countries (United Nations 2020).

Milk Microbiota

Milk's high nutritive content promotes the growth of a diverse range of microorganisms (Addis and others 2016). Young and colleagues (2015) investigated the constituents and uniqueness of the microbiota of feces, milk leukocytes, and blood leukocytes in healthy lactating cows using metagenomics and discovered the inclusion of a few bacterial operational taxonomic units

(OTUs) relating to the *Ruminococcus* and *Bifidobacterium* genera and also the *Peptostreptococcaceae* family in samples from these animals (Young and others 2015). From a microbiological standpoint, the safe handling of milk are important considerations. Thus, it is crucial to evaluate the constituents and emergence of raw milk microbiota, as well as their impact on the characteristics and structure of milk and its derived products (Addis and others 2016).

Microorganisms in Dairy Products

Lactic acid bacteria make up the majority of fermentation starters, and several of them are also intrinsic properties of the gastrointestinal microflora (James and others, 2020). *Lactobacillus*, *Leuconostoc*, *Pediococcus*, *Lactococcus*, *Streptococcus*, *Streptococcus*, *Carnobacterium*, *Enterococcus*, *Oenococcus*, *Tetragenococcus*, *Vagococcus*, and *Weissella*, are all genera in the order *Lactobacillales*.

Lactic acid bacteria are nonspore-forming gram-positive cocci, coccobacilli, or rods. They are anaerobes in general, lack catalase, and ferment glucose mainly to lactic acid or CO² and ethanol (James and others, 2020). Dairy products have a short shelf life in developing countries because they are an enhanced growth medium for a wide variety of organisms, including *Listeria monocytogenes*, *Staphylococcus aureus*, *Escherichia coli*, *Bacillus subtilis*, *Mycobacterium bovis*, *Brucella abortus*, and *Coxiella burnetii* (Rakhmanova and others 2018).

Industrial production process of dairy products in developed countries

Milk collection process

New technologies in the dairy industry are gradually being integrated, both at the farm level and in the dairy processing plant. The cows enter the parlor without provocation, and some cows are milked multiple times a day, resulting in higher milk product for the farmer. The tags on the cows enable integration into machines that collect massive amounts of data, such as the number of steps taken, the amount of curd chewed, and so on (Scano and others 2014). Technological improvements that aid in the monitoring of milk quality include subjecting the obtained milk to spectrophotometric and chromatographic techniques to assess milk quality (Zacharski and others 2016).

Milk processing

The weighbridge is used to transport milk to the milk processing plant, and the weight of the milk is automatically recorded. The temperature should be between 4 and 6°C. Sterile containers are used to obtain milk samples and conveyed to a laboratory technician for thorough analysis (Zacharski and others 2016). A lesser quality rating is given to milk that differs from normal milk in composition, taste, and smell. A composite sample is taken from each chamber in the refrigerated truck, which is compartmentalized to decrease milk sloshing. Acidity, antibiotics, added water, fat, and protein content are all checked in each

compartment's samples (Zacharski and others 2016).

Dairy processing stages

After passing initial analytical review tests, raw milk in the milk container truck is delivered to whole milk intake bays, where the milk pipes are attached. Milk is pumped into milk silos, which are large bulk storage tanks. While being poured into the silo, unloaded milk is instantaneously cooled to 4–6°C by a heat plate exchanger (HPE) (Zacharski and others 2016).

Separation, clarification, and centrifugation of Milk

Milk often must be asserted upon arrival at the dairy to eliminate dirt particles such as sand, soil, dust, and precipitated protein, which protects downstream processing equipment. In addition, centrifugation and microfiltration techniques can be used to remove bacteria, spores, and somatic cells from milk (James and others, 2020).

Reduced microbial load at this point can reduce biofilm burden (Zacharski and others 2016), allowing the heat plate exchanger (HPE) to operate more effectively. Milk bacterial clarification also enhances shelf life and organoleptic properties of dairy products while avoiding problems during cheese aging. Clarifiers and milk separators are both centrifugal separators, but their functions are slightly different. Although any centrifuge can be used as a clarifier, only centrifuges with a large hydraulic capacity are typically used for this purpose. The clarifier can work with cold (below 8°C) or hot (50–60°C) milk (Derakhshani, 2018).

The alteration of fat and solids-not-fat (SNF) amounts in milk, i.e. increasing or reducing these levels, is referred to as milk standardization. This is routine is carried out regularly for consumer milk supply as well as the manufacturing of other milk products such as condensed milk, milk powder, ice cream, and cheese. The goal of standardization is to ensure that the overall dairy product has a consistent milk fat content (James and others, 2020).

Pasteurization of the Milk

Pasteurization was first used to regulate *Mycobacterium bovis* causing tuberculosis (TB). This is no longer a concern because cows are examined for TB yearly and excluded from herds if the y test positive (Pexara and others 2018). Although the TB *bacillus* is a heat-resistant microorganism, *Coxiella burnetii*, the cause of Q fever in humans (Enright and others 1957), required pasteurization at 161°F (71.7°C) for 15 seconds, which is now the official standard for milk pasteurization. The standard vat pasteurization is 63°C (145°F) for 30 minutes (Pexara and others 2018).

Unpasteurized milk is 150 times more prone to trigger foodborne illness and 13 times more probable to lead in hospitalization than pasteurized dairy products, according to the US Centers for Disease Control (CDC). *Salmonella spp.*, *E. coli*, and *Listeria monocytogenes* are among the bacteria that can cause illness, which is why milk is pasteurized (USDA-FSIS 2018). Post-pasteurization contamination, on the other hand, has been discovered to be the most common cause of microbial outbreaks linked to milk products (Olsen and others 2014).

Factors that Potentially Contribute to the Safety of Milk and Dairy Products in developing countries

Natural Antimicrobial Systems in Milk

Lactoferrin, lactoperoxidase, lysozyme, and N-acetyl-β-D-glucosaminidase are natural antimicrobial peptides and enzymes found in raw milk that may improve its microbial safety. Within the first 3–4 hours after milk harvesting at ambient temperatures, these natural inhibitory systems in milk may inhibit a significant rise in microbial loads (Bruni and others 2016). Lactoferrin's antimicrobial effects can be direct, such as bacteriostatic and bactericidal activity, or indirect, such as activation of a complex series of reactions that result to a protective immune response in the aftermath of microbial infections (Giansanti and others 2016).

Lactoperoxidase is the scientific name for this natural system (LP-system) (Sarikaya

and others 2015; Sarr and others 2018). When oxidized by free sulphhydryl groups, these hypothiocyanite ions have a potent bacteriostatic impact against most mesophilic bacteria found in raw milk (Bruni and others 2016). Antiviral properties have also been reported for lactoperoxidase. The activation of the LP-system aids in the slowing of microbial growth while transporting raw milk in remote areas where smallholder dairy producer as is the case in many underdeveloped nations (Koksal and others 2016).

Lysozyme is a milk enzyme that works in tandem with several other antimicrobials to improve the shelf-life of raw milk. Lysozyme's antibacterial activity is enhanced when it is combined with lactoferrin or immunoglobulin A (Cosentino and others 2016).

Traditional Milk Processing Methods

Raw milk is processed into a variety of traditional products in Africa, including cheese (Mattiello and others 2018). Consumption of raw, unpasteurized milk and other dairy products has been shown to portray real health risks due to the possibility of human pathogen contamination (Verraes and others 2015). As a result, various preventative measures should be implemented during the manufacturing, handling, and processing of milk to boost consumer safety (Agyei and others 2019).

In Africa, traditional milk processing employs a variety of unit operations or techniques that may help to improve milk safety. Thermal treatments, fermentation, and the use of antimicrobial additives during production are examples of these processing methods or operations (Mattiello and others 2018).

Heat Treatment as a Milk Processing Methods

Heat treatment can considerably minimize or eliminate the microbial risks related to the consumption of raw milk (James and others 2020).

Heat treatment of milk can be classified as thermization (57°C–68°C for 15–20 s), pasteurization (60°C–65°C for 30 m or 71–74°C for 15–40 s), or sterilization (110°C–120°C for 10–20 min), which involves ultra-high temperature (UHT; 135–140°C for 6–10 s for indirect and 140–150°C for 2 s (Derakhshani, 2018).

Pasteurization can eliminate all vegetative microorganisms, including vegetative human pathogenic cells of *E. coli*, *Salmonella spp.*, *L. monocytogenes*, *Yersinia enterocolitica*, *Campylobacter jejuni*, enterotoxin producing *S. aureus* and *Clostridium botulinum* which may be present in raw milk (Claeys and others 2013).

Pasteurization also does not kill the heat-resistant spores of *C. botulinum* or *B. cereus*. Sterilization treatments are thus suitable for destroying vegetative and spores of most pathogens. Sterilization can kill spores of most pathogens, including *C. botulinum* and *B. cereus*, with the exception of some non-pathogenic thermoresistant *Bacilli*. Additionally, sterilization techniques can destroy preformed toxins of *S. aureus* and *C. botulinum* in milk, as well as *B. cereus* enterotoxins (Claeys and others 2013).

Raw milk is also frequently boiled or pasteurized during the process of fermentation dairy products for safety and technological reasons. Raw cow milk is heated to between 65°C and 80°C for about 30–50 minutes during the production of *nyarmie* and *fènè*, fermented yoghurt-like products in Ghana and Mali, respectively (Owusu-Kwarteng and others 2017). Similarly, in the traditional refining of milk into *amabre* and *mursik* in Kenya (Nieminen and others 2013; Nyambane and others 2014), *makamo* in Uganda (Schutte 2013), and *Pendidaam* in Cameroon, raw milk may be heated before fermentation occurs (Owusu-Kwarteng and others 2017).

Natural Fermentation as a Milk Processing Methods

Fermentation of milk is inexpensive and most convenient technique of extending the shelf life of milk for the large percentage of smallholder dairy farmers in developing

countries. Back-slopping or spontaneous fermentations are common in traditional dairy fermentations (Agyei and others 2019). As a result, these processes do not use properly defined starter cultures, and fermentation occurs under uncontrolled conditions (Owusu-Kwarteng and others 2017). Commensal microorganisms present in collection and fermentation containers, the environment, or the hands of processors start and carry out the fermentation process. Lactic acid bacteria (LAB) and yeasts are primarily involved in local dairy product fermentation. (Jans and others 2017).

Traditional fermented foods are generally thought to be safe due to the release of antimicrobial compounds by fermenting bacteria and the decrease in pH, both of which help to prevent pathogenic microorganisms from growing. The production of organic acids by LAB and yeast metabolic activities causes a significant drop in pH. Additionally, during LAB and yeast fermentation, compounds including diacetyl, hydrogen peroxide, and carbon dioxide are secreted (Patrovsky and others 2016).

Use of Antimicrobial Additives as a Milk Processing Methods

Traditional milk preparation in some developing countries employs the use of various medicinal plant parts. For example, before fermenting pasteurized milk into *kule naoto*, Maasai people in Kenya add extracts of *Lippia javanica* (stem), *Olkingiri* (stem), or *Olea europea* (root). When making *kule naoto*, pretreating the fermenting gourd with ashes or charcoal remains of *Olea africana* before filling it with pasteurized milk improves the quality and safety of the dairy product (Nduko and others 2017).

Microbial counts were observed to be lower in plant extract fermented milk than in control, despite the fact that the pH was significantly high in the plant extract-fermented milk (Onyango and others 2014). The gourd is sanitized during *mursik* production by burning *Senna didymobotrya* sticks before being filled with pasteurized milk for fermentation.

Similarly, the fermentation of camel milk into *suusac* is initiated by smoking the gourd (fermentation vessel) with *Acacia seyal* (Nduko and others 2017), a method that is intended to remove pathogenic and spoilage microorganisms prior to the fermentation process, ensuring the final product's safety (Owusu-Kwarteng and others 2017).

SAFETY OF DAIRY PRODUCTS

The dairy industry relies heavily on the application of ways to enhance and boost milk process optimization. To effectively kill disease-causing pathogens like *E. coli* 0157:H7, milk must be pasteurized first. It is important to check and maintain the quality of milk at the grass-roots level in order to meet the recognised quality standard (Kavitha and Archana 2015).

Area of quality control for Dairy Production Process

The farm

Quality assurance and control must begin on the farm where milking is performed (Mansel 2010), with the use of accredited milk production and handling practices, as well as adherence to regulations regarding the use of veterinary drugs on lactating animals and regulations against milk adulteration, among other things (Kavitha and Archana 2015).

Milk collection centers

All milk obtained from various farmers with significant management activities or milk bulked from varied collecting centers must be tested for wholesomeness, bacteriological, and chemical quality (Kavitha and Archana 2015).

Dairy factory and within the dairy factories

Following the acceptance of milk from various farmers and collection centers, the dairy factory is responsible for ensuring that the milk is treated hygienically and processed into various products (Mansel 2010).

Marketing of processed products

Any country's government employs public health authorities who follow the law to inspect the food quality ingredients sold for public consumption and may refuse to consume substandard or contaminated foodstuffs, potentially leading to criminal

prosecution of the perpetrators (Kavitha and Archana 2015).

Milk quality indicators

Quality milk has a conventional molecular structure, is free of pathogens and toxins, is free of dirt, has a low titratable acidity, a good taste and aroma, is adequate in preserving quality with a low microbial load (Kavitha and Archana 2015).

Good Agricultural Practices (GAPs)

Good Agricultural Practices GAPs are practices that ensure on-farm (and post-production) practices are environmentally, economically, and socially sustainable, leading to high-quality food and non-food agricultural products. These are used to account for food safety risks posed by the environment, agricultural inputs, workers, and other factors (Kavitha and Archana 2015).

Good Hygiene Practices (GHP)

At all levels of the food chain, all procedures relating to the conditions and process was undertaken to guarantee the food been safe. These include appropriate facility design, insightful machinery construction, product recall management, waste disposal, pest control, product contamination control, and quality control management (Kavitha and Archana 2015).

Hazard Analysis and Critical Control Points (HACCP)

HACCP stands for Hazard Analysis and Critical Control Points, and it is a science-based system for systematically identifying, evaluating, and controlling food safety hazards. From acquisition of raw materials, purchasing, and handling to industrial production, delivery, and intake of the final product, quality control is handled through the monitoring and processing of biological, chemical, and physical hazards (Kavitha and Archana 2015).

Total Quality Management and Quality Assurance Program

Consumer and government concerns about the potential for chemical contaminants on farms to enter the food supply are a major factor influencing livestock industry policy.

Chemical contaminants, particularly antibiotic residues in raw milk shipped from the farm, are one of the goals of total quality management (Kavitha and Archana 2015).

Nutritional Benefits of Dairy Products

Many dairy foods are a well-known origin of supplements for growing adolescents (Murphy and others 2016).

1. Calcium: Helps build and maintain strong bones and teeth
2. Riboflavin: Body growth, red blood cell production, and metabolism are all aided by this supplement.
3. Phosphorus: bone Strengthening
4. Vitamin D: aid in calcium absorption
5. Pantothenic Acid: conversion of food to energy
6. Potassium: maintaining of blood pressure and balancing of body fluid
7. Vitamin A: healthy skin and aid in good vision
8. Niacin: boost proper circulation
9. Magnesium: promotes the functioning of the nerve and muscle and also supports the immune system
10. Conjugated linoleic acid (CLA): promotes weight loss
11. Omega 3 fatty acids: helps in clotting of blood by production of hormones (Murphy and others 2016).

Health Benefits of Dairy Products

The health benefits of dairy products include;

1. Digestion

Probiotics are commonly found in fermented milk products including yoghurt, culture drinks, and kefir. These foods are excellent vehicles for probiotics because milk's content (which includes carbohydrate, protein, and fat) acts as a safe matrix, allowing probiotics to thrive from the digestive system to the gut, and also adverse stomach conditions (Agyei and others 2019).

2. Improve the Gastrointestinal Health

Probiotics have been associated with decrease in the frequency and intensity of diarrheal disease with acute infectious diarrhea. Probiotics are also said to minimize ulcerative colitis relapses and maintain the digestive discomfort (IBS) (Agyei and others 2019).

3. Dental health

More than just excellent dental hygiene is required to achieve good oral health. Teeth can also be kept healthy through healthy food and eating habits. Dairy foods play a unique role in dental health because they comprise of unique combination of anti-decay nutrients like calcium, phosphorus, and casein, a protein (Agyei and others 2019).

4. Weight management

A healthy weight maintenance is achieved by balancing the amount of energy consumed (kilojoules from food) with the amount of energy expended (kilojoules burned) via daily tasks or workout (Agyei and others 2019).

5. Muscle mass

Protein after a workout is popular for helping to develop lean muscle mass. Milk proteins (whey and casein) are routinely added as nutrition supplements aimed at preserving or increasing muscle mass. Dairy products contain high-quality proteins that supply all of the essential amino acids required for muscle growth and maintenance (Agyei and others 2019).

6. Immune Health

Probiotics have been shown to decrease the occurrence of upper respiratory infections in adults and also the severity flu-like and common cold symptoms in children, according to studies. Evidence shows that eating yogurt can help prevent yeast infections (Agyei and others 2019).

7. Healthy Heart and Blood Pressure Control

Dairy foods contain the minerals calcium, potassium, and magnesium which help in maintaining the blood pressure. Potassium, in particular, aids in maintaining a healthy blood pressure by regulating fluid and mineral

balance in the body. There are more effects of dairy on cardiovascular health (Agyei and others 2019).

8. Strengthening the Bone

Bones are living tissue that is continually renewing, it is critical to develop and strengthen them from young age to old age. Calcium-rich foods like milk, cheese, and yoghurt, are all essential components for bone strength for life (Claeys and others 2013).

9. Reduced Risk of Type 2 Diabetes

Dairy products can help prevent type 2 diabetes. It boosts insulin sensitivity, making the body more capable of controlling blood sugar levels (Agyei and others 2019).

CONCLUSION

Traditional milk products are considered extremely important in every geographical area studied. When milk is fermented and retailed in an urbanized, or villages using empirical methods, or when the magnitude and techniques of producing has progressed to the commercial dairy sector, with its linked sales and promotion practices. In developing countries, industrial production of dairy products using LAB can help to boost product safety standards while also boosting their economies through revenue generation. This is in addition to the health benefits that these dairy products provide.

According to the features and techniques described, local dairy products are generally produced under primitive settings in underdeveloped countries, leading to decreased yields and low quality of milk products. Many contributions emphasize the significance of national and international policies that recognize the significance and worth of the dairy industry's traditional milk product sector, and suggest that this sector be considered in future policies as needed.

Recommendations

1. The importance for enhanced veterinary control of cattle to guarantee a secured milk supply is the starting point for recommendations for the development of traditional milk products.

2. Dairy production hygiene improvement programs,
3. Creation of village-based milk operation facilities,
4. Modifications in industrial plants to enhance productivity and quality of products,
5. Tutoring of dairy farmers and milk manufacturers to improve their skills and knowledge,
6. Technical assistance for this livestock farming sector.
7. To minimize potential threat resulting from the ingestion of varying dairy products, all manufacturers, retailers, including dairy farmers, and consumers, are obligated to take the appropriate measures to ensure the quality and safety of dairy products.
8. Policymakers and regulatory bodies serve a significant part in establishing national and international control systems and regulations, along with examination and monitoring, to guarantee that dairy products are processed, transported, and kept in storage in collaboration with all stakeholders.
9. When developing and implementing control measures and standards, it is important to consider the unique characteristics of the dairy chain in each underdeveloped nation.
10. Certification program to recognize small-scale dairying and informal markets would be critical in safeguarding milk and dairy products in underdeveloped nations.

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