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Meet the editors

Dr. Salam A. Ibrahim is a food science research professor in the food and nutritional sciences program at North Carolina A&T State University. Dr. Ibrahim established a research program in dairy starter cultures, food safety, and probiotics. He has successfully conducted projects that were funded by the NIFA-USDA, DHS, other funding agencies, and the private sector. Many of his funded projects have focused on the isolation of beneficial strains and the functional characterization of related health benefits. Dr. Ibrahim became specifically interested in the characteristics of Lactobacillus bulgaricus and the effects it has on the quality of yogurt. Currently, he is interested in isolating novel bacterial strains of L. bulgaricus and other lactic acid bacteria, as well as novel delivery systems and new food applications.

Dr. Tahl Zimmerman is an expert biochemical food scientist and Food and Nutritional Sciences lecturer at North Carolina Agricultural and Technical State University. His research interests include the functionality and preservation of probiotic bacteria in dairy products and the development of novel food safety applications. Dr. Zimmerman recently identified choline kinase as an antimicrobial target in Gram-positives as well as a new technique for monitoring the activity of this enzyme. He is currently working to apply this new knowledge in the preservation of food products, including dairy products. Dr. Zimmerman has also developed several dairy-based classroom and lab exercises designed to improve students' understanding of biochemistry and other basic sciences underlying Food Sciences and has worked hard to improve the curriculum at North Carolina A&T.

Dr. Rabin Gyawali is a research scientist (microbiologist) of food science. His research focuses on various aspects of food microbiology and safety. In particular, his research interests relate to dairy science, food fermentation, probiotics and prebiotics, natural antimicrobials, food safety, and human health. To date, he has published more than twenty peer-reviewed articles and six book chapters dealing with these topics.

Contents

Preface

The dairy industry has faced several challenges that impact dairy food quality and consumer acceptability. As a response to these challenges, this book presents a different approach to address these issues facing the dairy industry and includes seven chapters dealing with dairy processing, probiotic characteristics, and current issues related to consumers. The book is divided into four sections and begins with an introductory section that describes the background and history of dairy science along with recent developments. The second section is related to dairy processing technology and covers drying processes and by-product utilization. The third section of the book consists of two chapters that address dairy supply chain risks and issues related to consumer decisions about dairy products. Finally, the last section deals with dairy foods as functional food products and the probiotic characterization of yogurt starter culture.

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Section 1

Introduction

Chapter 1

Introductory Chapter: Overview of Trends in Dairy Science and Technology

Tahl Zimmerman, Rabin Gyawali and Salam A. Ibrahim

1. Introduction

Dairy science and technology is a field that encompasses the production and manufacturing of all dairy products as well as the machinery and methods used in the dairy industry. The largest part of the food supply chain is, by far, the dairy industry. This industry is an integral part of our food economy that not only supplies consumers with many ready-to-eat products such as milk, butter, and cheese but also produces many of the ingredients like milk powder and condensed milk that are found in processed foods. Milk itself has also become a key ingredient for the deployment of probiotics and the development of functional food products designed to improve consumer health. As such, dairy products have become an area of accelerated research and innovation, particularly in the areas of processing, sustainability, and health, and marketing strategy.

2. Historical reviews and developments

Milk has been a source of sustenance for newborn offspring since the emergence of mammals: all species of which produce milk to sustain their young [1]. Meanwhile, the practice of domesticating other mammalian species for milk production and consumption is so ancient; it predates written records [2]. In fact, prehistoric baby bottles have recently been uncovered in Bavaria, Germany, indicating that animal milk was used as far back as the Bronze Age to feed infants [3]. The discovery of animal milk as a food source was an important achievement because a sustainable food source that could meet human physiological needs for energy, water, and nutrients was then available [2]. All of the animal species originally exploited for milk, including cows, buffaloes, camels, sheep, yaks, goats, horses, and camels, are still used today for that purpose as milk and milk products continue to be a diet staple in many cultures around the world [4].

The role of milk in traditional diets varies according to climate. For example, milk does not play a role in the diet of many tropical cultures as much as in temperate Northern Europe, where far higher volumes of milk and milk products are produced and consumed [5]. This is most likely simply due to the fact that, with a lack of refrigeration, warmer climates make milk refractory to long-term storage [5]. In these warmer climate cultures, milk has traditionally been consumed immediately or otherwise preserved by boiling or processing into more stable products such as fermented milks [6].

Advances in the technology of milk production have occurred only relatively recently. The milk homogenizer was patented in 1899. This device was designed to break up milk globules in order to give milk the consistency that we take for granted today [7]. Automated milking systems appeared nearly a century later [8]. Milk production and biotechnology intersected in the 1990s with the advent of recombinant bovine growth hormones that were used to provoke an increase in milk production per cow [9] and the approval by the FDA of cloned animals for milk production in 2008 [10]. Recently, automated cell counters have emerged which can be used for the early detection of bovine mastitis [11].

Dairy product safety is an important issue because milk, being nutrient dense, not only serves as a medium that supports the growth of beneficial fermentative microflora [12] but is also a medium in which pathogenic species can proliferate [13]. The first dairy safety technologies included the invention of the process of pasteurization in the nineteenth century by Louis Pasteur, a technique adopted universally in the USA in 1917 [14]. The first milk safety packaging was glass milk delivery bottles invented by Henry Thatcher [15]. Milk tankers appeared in 1914 [16], and milk cartons became ubiquitous by 1974 [17]. In very recent years, cold pressure processing has been developed as an alternative to pasteurization [18]. Pulse electric field [19], ultra-sonication [20], and irradiation [21] have also been explored as alternatives. Meanwhile, dairy supply chains have become more centralized, leading to emerging issues in dairy safety. Hazard analysis and critical control point (HACCP) management programs have been developed to help neutralize biological, physical, and chemical hazards. HACCP mandates risk assessments at different points in the production process [22]. These programs demand continuous monitoring of the microbiota of both the dairy products and the production environment which has led to a new demand for rapid methods of microbiological detection and identification. As a result, novel rapid and high-precision techniques such as qPCR [23] and enzyme immunoassays [24] have been developed to identify milk pathogens such as *Campylobacter* and *Escherichia coli* O157:H7.

Another key achievement of mankind in the area of nutrition was the accidental discovery of bacterially fermented products from the milk of the domesticated species mentioned above [25]. Instead of being considered spoiled, these products entered the human diet as nutritional food products. Long before refrigeration existed and microbes were discovered, fermentation was adopted as an ancient method of preserving milk. As such, traditional fermented milk products are found in many cultures. These products include dadiah, the traditional fermented buffalo milk from West Sumatra; filmjölk, from Scandinavia; and the eastern European kefir.

Yogurt is the fermented milk product most widely distributed in the West and is thought to have been invented in 5000 B.C. Yogurt has also been known to be a health food for a long time: its health benefits are mentioned in the Vedas and in the Old Testament [26]. The type of yogurt we know today originated from the Balkans and is produced using a culture of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* bacteria. Yogurt was popularized in Europe and the USA in the first decade of the twentieth century by the scientist Élie Metchnikoff [27]. Metchnikoff believed that this fermented milk product promoted good health and ultimately longevity by supporting a balance of beneficial bacterial microflora in the gut [28]. The original hypotheses and observations regarding the first "probiotic" and the effects it had on health have since led to the proliferation of probiotic food products, supplements, and functional foods that we see on the market today. The number of these products has increased with the discovery of novel beneficial species of gut bacteria and the development technologies that can support the delivery of viable bacteria to the consumer [29]. However, there is some controversy over whether or not the species of bacteria found in the original Balkan product can be considered a probiotic.

Cheese was similarly discovered in ancient times when fermented milk was found to fractionate into a liquid and a coagulated solid that was protein rich. The liquid, known as whey, was drained, leaving a solid curd to be stacked and dried during an aging process to produce cheese [30]. Cheeses, particularly hard cheeses, maintain their nutritional value for long periods of time. In addition, because it contains little lactose, cheese can command an advantage over milk for consumers who are lactose intolerant [31]. In a later discovery, rennet, an enzyme found in the stomach lining of cows, was found to quicken the coagulation process. Medieval clergymen later tinkered with the aging processes and the use of rennet to give us the hard cheeses like Parmesan, Gruyère, Roquefort, and Munster [32]. Modern technologies have focused on standardizing milk inputs, such as by diafiltration [33], and creating cheeses with the functional properties taste, color, melt, and mouth feel that are considered desirable by the end user [34], such as by adding adjunct species during the fermentation process [35]. In addition, there are areas of intensive research with the aim of reducing production time. These include developing strategies for preventing bacteriophage infections that might slow the acidification process during fermentation by exploiting host bacteriophage resistance and defense mechanisms [36] and finding methods to speed up the curd drying process [37].

The functional properties associated with cheese include the following: flavor/aroma, which is a result, in part, of protein and fat content; viscosity, which is determined by the liquid phase of the milkfat; texture/mouthfeel, stretch, which depends on pH, relative fractions of colloidal calcium phosphate, and the proportion of casein proteins that remain intact; browning during baking, which occurs due to a reaction between lactose and proteins; and freezing ability, which is the ability to be frozen and retain physical properties. Research in the area of functional properties of cheeses is ongoing as new products are created in response to demands by the end user. For example, due to some of the negative health effects of saturated fats, low-fat alternatives have been developed. However, additives are needed to compensate for the lack of fats so that the properties of the cheese do not change with respect to normal fat cheese [38]. Another aspect of functionality is associated with the health benefits that the components of cheese provide. For example, beneficial bioactive peptides, oligosaccharides, and fatty acids are found in cheeses such as Parmesan and Gouda. The health benefits of these bioactives can include a reduction in hypertension and blood sugar as well as immune system modulation [39].

Modern industrial production of soft cheeses and Greek yogurt generates large quantities of liquid acid whey byproducts, which are environmentally unfriendly and costly to transport and dispose of [40]. One solution that has been attempted is to transfer liquid whey to farmers for use as a crop fertilizer [41]. However, transportation costs for high volumes are high. In addition, limited amounts of acid whey can be disposed of in this fashion because runoff can lead to acidification of nearby water supplies. Such additional contamination in water can lead to algal blooms and a resultant drop in dissolved oxygen which is lethal for aquatic animal species [42]. For this reason, a method for converting the liquid whey by-product into a usable product in other processed food products or to limit the production of whey [43] are active areas of research. Some possible solutions that have been proposed are to process the lactose found in this by-product for use as a sweetener [44] or to use microfiltration technologies to separate out specific proteins that can be used as functional ingredients in other food products [45]. However, the vast quantities of acid whey produced by the dairy industry remain an ongoing problem in search of innovative solutions.

3. Dairy foods in human nutrition

Recognizing the importance of milk in the human diet, the USDA has promoted the consumption of milk since at least the mid-twentieth century. For example, the National School Lunch Act of 1946 mandated that milk be included in subsidized school lunches. Meanwhile, the Child Nutrition Act of 1966 and the Special Milk Program led to the provision of free milk to schools that did not participate in other nutrition programs. In 1990, the Fluid Milk Promotion Act was passed in order to authorize the USDA to conduct campaigns to increase consumer purchases of liquid milk. Since then, the "Got Milk" campaign began in 1993 as a way to counter the rise in the consumption of sugary soft drinks as a primary beverage. This campaign was replaced by the "Milk Life" campaign in 2014 that emphasized lifestyle choices. In 2004, the "3-A-Day" advertising campaign was introduced which promoted a link between milk products and the health benefit of weight loss (this campaign was later discontinued in 2007 to due complaints to the Federal Trade Commission of the lack of evidence for this claim). Private initiatives were also carried out, such as the formation of Dairy Management, Inc. to promote the sale of milk. Beginning in 2015, the issue of low milk sales took particular prominence due to the drop in sales of dairy products vs. non-milk plant-based products. Since then, research into how best to promote the sale of liquid milk has been welcomed [46]. Another recent development in human nutrition is related to the establishment of "my plate." It replaced the USDA's MyPyramid guide on June 2, 2011, ending 19 years of USDA food pyramid diagrams. This clearly demonstrated that dairy foods become part of modern healthy diet.

The primary purpose of this book is thus to explore a cross section of current trends in dairy science with respect to safety, sustainability, processing, health, and marketing. Food safety risks in the dairy supply chain will be explored as well as systematic discovery of marketing messages designed to appeal to the dairy consumer. We will look at some of the technology improvements in manufacturing processes, the exploitation of waste products, and new frontiers in the production of functional cheese products. In addition, we also reopen the issue, originally proposed by Metchnikoff, that the species of bacteria found in yogurt is the reason for yogurt's health benefits, with an emphasis on the particular properties and benefits of *L. bulgaricus*, one of two primary species used in the fermentation of yogurt products. Other trends left unexplored are the search for antimicrobial targets that can be exploited in food safety applications [47, 48] and gaining a better understanding of the process of autolysis, which is fundamental to cheese making and probiotic stability [49], and the role of prebiotics in health promotion [50].

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References

[1] Oftedal OT. The evolution of milk secretion and its ancient origins. Animal. 2012;**6**(3):355-368

[2] Curry A. Archaeology: The milk revolution. Nature. 2013;**500**(7460): 20-22

[3] Dunne J, Rebay-Salisbury K, Salisbury RB, Frisch A, Walton-Doyle C, Evershed RP. Milk of ruminants in ceramic baby bottles from prehistoric child graves. Nature. 2019;**574**(7777):246

[4] Barlowska J, Szwajkowska M, Litwinczuk Z, Krol J. Nutritional value and technological suitability of milk from various animal species used for dairy production. Comprehensive Reviews in Food Science and Food Safety. 2011;**10**(6):291-302

[5] Hernandez-Castellano LE, Nally JE, Lindahl J, Wanapat M, Alhidary IA, Fangueiro D, et al. Dairy science and health in the tropics: Challenges and opportunities for the next decades. Tropical Animal Health and Production. 2019;**51**(5):1009-1017

[6] Falvey L, Chantalkhana C. Smallholder Dairying in the Tropics. Nairobi: International Livestock Research Institute; 1998

[7] Wilbey RA. Homogenization of Milk: Principles and Mechanism of Homogenization, Effects and Assessment of Efficiency: Valve Homogenizers. Encyclopedia of Dairy Sciences. 2011. pp. 750-754

[8] Castro A, Pereira JM, Amiama C, Bueno J. Estimating efficiency in automatic milking systems. Journal of Dairy Science. 2012;**95**(2):929-936

[9] Dohoo IR, Leslie K, DesCoteaux L, Fredeen A, Dowling P, Preston A, et al. A meta-analysis review of the effects of recombinant bovine somatotropin 1. Methodology and effects on production. Canadian Journal of Veterinary Research. 2003;**67**(4):241-251

[10] Tanne JH. FDA approves use of cloned animals for food and milk. British Medical Journal. 2008;**336**(7637):176-176

[11] Sørensen LP, Bjerring M, Løvendahl P. Monitoring individual cow udder health in automated milking systems using online somatic cell counts. Journal of Dairy Science. 2016;**99**(1):608-620

[12] Hayek SA, Gyawali R, Aljaloud SO, Krastanov A, Ibrahim SA. Cultivation media for lactic acid bacteria used in dairy products. Journal of Dairy Research. 2019;**86**(4):490-502

[13] Garcia SN, Osburn BI, Cullor JS. A one health perspective on dairy production and dairy food safety. One Health. 2019;**7**:100086

[14] Steele JH. History, trends, and extent of pasteurization. Journal of the American Veterinary Medical Association. 2000;**217**(2):175-178

[15] Lockhart B, Pete S, Serr C, Lindsey B. The Dating Game: Thatcher Glass Mfg. Co. Bottles and Extras. 2007

[16] Rankin SA, Bradley RL, Miller G, Mildenhall KB. A 100-year review: A century of dairy processing advancements—Pasteurization, cleaning and sanitation, and sanitary equipment design. Journal of Dairy Science. 2017;**100**(12):9903-9915

[17] Robertson G. The paper beverage carton: Past and future. Food Technology Magazine. 2002;**56**(6)

[18] Chawla R, Patil GR, Singh AK. High hydrostatic pressure technology in

dairy processing: A review. Journal of Food Science and Technology. 2010;**48**(3):260-268

[19] Mohammed MEA, Amer Eiss AH. Pulsed Electric Fields for Food Processing Technology. In: Structure and Function of Food Engineering; 2012. Available from: https://www.intechopen.com/

[20] Nguyen NHA, Anema SG. Effect of ultrasonication on the properties of skim milk used in the formation of acid gels. Innovative Food Science & Emerging Technologies. 2010;**11**(4):616-622

[21] Odueke OB, Farag KW, Baines RN, Chadd SA. Irradiation applications in dairy products: A review. Food and Bioprocess Technology. 2016;**9**(5):751-767

[22] van Schothorst M, Kleiss T. HACCP in the dairy industry. Food Control. 1994;**5**(3):162-166

[23] Zhou B, Liang T, Zhan Z, Liu R, Li F, Xu H. Rapid and simultaneous quantification of viable *Escherichia coli* O157:H7 and Salmonella spp. in milk through multiplex real-time PCR. Journal of Dairy Science. 2017;**100**(11):8804-8813

[24] Law JW-F, Ab Mutalib N-S, Chan K-G, Lee L-H. Rapid methods for the detection of foodborne bacterial pathogens: Principles, applications, advantages and limitations. Frontiers in Microbiology. 2015;**5**:770

[25] McFarland LV. From yaks to yogurt: The history, development, and current use of probiotics. Clinical Infectious Diseases. 2015;**60**(suppl 2):S85-S90

[26] Shah NP. Yogurt in Health and Disease Prevention. London: Academic Press, an imprint of Elsevier; 2017. p. xxviii, 542 p

[27] Bibel BJ. Elie Metchnikoff's bacillus of long life. ASM News. 1988;**54**(12):661-665

[28] Metchnikoff E, Mitchell PC. The Prolongation of Life: Optimistic Studies. New York & London: G. P. Putnam's Sons; 1908. p. 1 p.l., v -xx p

[29] Song D, Ibrahim S, Hayek S. Recent application of probiotics in food and agricultural science. In: Probiotics. 2012. DOI: 10.5772/50121. Available from: https://www.intechopen.com/

[30] Button JE, Dutton RJ. Cheese microbes. Current Biology. 2012;**22**(15):R587-R589

[31] Gross M. On the origins of cheese. Current Biology. 2018;**28**(20):R1171-R1173

[32] Kindstedt P. Cheese and Culture: A History of Cheese and Its Place in Western Civilization. White River Junction, Vermont: Chelsea Green Pub.; 2012. p. x, 253 p

[33] Gavazzi-April C, Benoit S, Doyen A, Britten M, Pouliot Y. Preparation of milk protein concentrates by ultrafiltration and continuous diafiltration: Effect of process design on overall efficiency. Journal of Dairy Science. 2018;**101**(11):9670-9679

[34] Ah J, Tagalpallewar GP. Functional properties of Mozzarella cheese for its end use application. Journal of Food Science and Technology. 2017;**54**(12):3766-3778

[35] Guidone A, Braghieri A, Cioffi S, Claps S, Genovese F, Morone G, et al. Effect of adjuncts on microbiological and chemical properties of Scamorza cheese. Journal of Dairy Science. 2015;**98**(3):1467-1478

[36] Siezen RJ, Kok J, Abee T, Schaafsma G. Lactic acid bacteria: Genetics, metabolism and applications—Proceedings of the

Seventh Symposium on Lactic Acid Bacteria: Genetics, Metabolism and Applications; 1-5 September 2002; Egmond aan Zee, The Netherlands. Antonie Van Leeuwenhoek International Journal of General and Molecular. 2002;**82**(1-4):1-1

[37] Fagan CC, Castillo M, Payne FA, O'Donnell CP, O'Callaghan DJ. Effect of cutting time, temperature, and calcium on curd moisture, whey fat losses, and curd yield by response surface methodology. Journal of Dairy Science. 2007;**90**(10):4499-4512

[38] Ardö Y. Flavour and texture in low-fat cheese. In: Law BA, editor. Microbiology and Biochemistry of Cheese and Fermented Milk. Boston, MA: Springer; 1997

[39] Santiago-López L, Aguilar-Toalá JE, Hernández-Mendoza A, Vallejo-Cordoba B, Liceaga AM, González-Córdova AF. Invited review: Bioactive compounds produced during cheese ripening and health effects associated with aged cheese consumption. Journal of Dairy Science. 2018;**101**(5):3742-3757

[40] Gyawali R, Ibrahim SA. Addition of pectin and whey protein concentrate minimises the generation of acid whey in Greek-style yogurt. Journal of Dairy Research. 2018;**85**(2):238-242

[41] Finaru AL, Gavrila L, Grosu L, Fernandez B, Grigoras CG, Patriciu OI, et al. Valorization of whey from dairy industry for agricultural use as fertiliser: Effects on plant germination and growth. Environmental Engineering and Management Journal. 2012;**11**(12):2203-2210

[42] Kavaz D, Öztoprak H. Environmental awareness of university students on white cheese waste water. Eurasia Journal of Mathematics, Science and Technology Education. 2017;**13**(12):8003-8015

[43] Gyawali R, Ibrahim SA. Effects of hydrocolloids and processing conditions on acid whey production with reference to Greek yogurt. Trends in Food Science and Technology. 2016;**56**:61-76

[44] Lindsay MJ, Walker TW, Dumesic JA, Rankin SA, Huber GW. Production of monosaccharides and whey protein from acid whey waste streams in the dairy industry. Green Chemistry. 2018;**20**(8):1824-1834

[45] Kavaz D, Öztoprak H. Environmental Awareness of University Students on Woodhead Publishing Series in Food Science, Technology and Nutrition. 2018:93-126

[46] Finnell KJ, John R. A social marketing approach to 1% milk use: Resonance is the key. Health Promotion Practice. 2017;**19**(3):437-444

[47] Zimmerman T, Ibrahim S. Choline kinase, a novel drug target for the inhibition of *Streptococcus pneumoniae*. Antibiotics (Basel). 2017;**6**(4):20. DOI: 10.3390/antibiotics6040020

[48] Zimmerman T, Lacal Sanjuan JC, Ibrahim SA. Choline kinase emerges as a promising drug target in gram-positive bacteria. Frontiers in Microbiology. 2019;**6**

[49] Zimmerman T, Gyawali R, Ibrahim S. Autolyse the cell in order to save it? Inducing, then blocking, autolysis as a strategy for delaying cell death in the probiotic *Lactobacillus reuteri*. Biotechnology Letters. 2017;**39**:1547-1551

[50] Gyawali R, Nwamaioha N, Fiagbor R, Zimmerman T, Newman RH, Ibrahim SA. The Role of Prebiotics in Disease Prevention and Health Promotion. Dietary Interventions in Gastrointestinal Diseases: Foods, Nutrients, and Dietary Supplements. 2019. pp. 151-167

Section 2

Dairy Food Processing Technology

Chapter 2

Study of the Kinetics of Vacuum Drying of Hard and Semihard Cheeses

Vladimir Ermolaev

Abstract

The chapter considers cheeses as an object of drying process. It describes the changes occurring in the cheese during the drying process. The results of experimental studies of cheese vacuum drying are presented as well. The kinetics of cheese vacuum drying is investigated. Such important indicator as the shrinkage losses of cheeses in the process of vacuum drying was studied. It has been established that cheese vacuum drying proceeds in two steps: at constant drying speed and at falling one. By graphic differentiation, the curves of the speed of cheese drying were constructed. It was determined by an analytical method that the moisture content of polymolecular adsorption for cheeses is 4–9%. The values of equilibrium moisture for cheese vacuum drying were established. The dependences of the coefficients of cheese shrinkage on the thickness of the drying layer, the shape, and size of grinding were obtained. When the thickness of the drying layer is from 10 to 30 mm, the coefficient of cheese shrinkage, depending on the shape and size of grinding, is from 3 to 14%. With an increase in the mass fraction of moisture in cheeses, the shrinkage coefficient increases as well.

Keywords: kinetics, vacuum drying, cheeses, temperature, shrinkage, moisture, drying the adjusted, heat, drying curves

1. Introduction

Considering cheese as an object of drying, it should be noted that the change in the cheese properties during the drying process depends on both the physicochemical properties, the structure, the binding forms of moisture in the material, and the thermophysical characteristics that take into account the features of mass and energy transfer.

The main structural elements of the cheese are the macrograins, the interlayer between the macrograins, the microvoids, and the micrograins. The basis of each macrograin structure is a protein network, in the cells of which numerous micrograins are interspersed in the form of fat drops, lipoid drops, and crystalline formations.

The transition of fat from milk to cheese depends on many factors. Most of the fat balls are transferred (under all other conditions) to medium-sized fat and then to small and large fat [1, 2]. Milk fat is considered to be the most valuable component of milk, although in terms of the nutrition physiology, milk proteins are superior in value to milk fat. Four factors determine the special significance of milk fat in milk and dairy products: economic value, nutritional value, taste, and physical properties of fat-containing dairy products caused by the presence of fat [2].

During maturation, all components of the cheese mass are exposed with profound changes; as a result of which, the proper consistency and drawing of this type of cheese are acquired [3].

Cheese humidity depends on the technological mode of production, temperature and duration of rennet clotting, temperature of the second heating stage, partial salting of the curd mass in the grain, and adding water during the second heating stage, as well as on the duration of the cheese grain processing. With a decrease in the clotting temperature and the temperature of the second heating stage, the moisture capacity of the curd and the water content in the finished product increase. As the temperature rises, the moisture content in the cheese decreases. Loss of moisture occurs at the stage of salting (osmotic transfer of water) and during the period of maturation (evaporation). The intensity of the microbiological and biochemical processes occurring in it depends on the value of the initial moisture content of the cheese (after pressing) [4].

According to the GOST (the RF standards and regulations) 7616-85, GOST 11041-88, and GOST R 52686-2003, the following dependence characterizes cheese: with an increase in the moisture mass fraction, the mass fraction of fat decreases. The mass fraction of fat and moisture of all objects of the current research is presented in **Table 1**.

For most solid and semihard cheeses, the mass fraction of fat in the dry matter is 45–50%, and the mass fraction of moisture is 40–44%.

The fat in the cheese is in the form of micrograins with a diameter of 10–15 microns. There are also larger inclusions of fat, the so-called fat drops, which are allocated evenly throughout the thickness of the cheese. Fat drops and lipid micrograins in cheese are milk fat destabilized in the process of cheese making and ripening. This judgment is justified, since at temperatures above 20°C, the fat in the cheese can be melted out of the cheese mass, which is the main obstacle in the thermal dehydration of the cheese.

Product name	Mass fraction (%)	
	Fat in the dry matter (no less than)	Moisture (no more than)
Hard cheeses with a high temperature of the second heat stage		
Sovetskiy	50	42
Swedish	50	42
Altaiskiy	50	42
Gornyiy	50	40
Moscowskiy	50	42
Semihard cheeses with a low temperature of the second heat stage		
Dutch	45–50	43–44
Kostromskoy	45	44
Poshekhonskiy	45	42
Yaroslavskiy	45	44

Table 1.
Mass fraction of fat and moisture of the research objects.

2. Materials and methods

The objects of research were cheeses of the following brands: Soviet, Swiss, Altai, Gorny, Moscow, Holland, Kostroma, Poshekhonskiy, and Yaroslavskiy.

For the experimental studies on the drying unit that was used, the scheme of which is shown in **Figure 1**.

This drying unit is universal and can be used for drying almost any raw material of plant and animal origin. The drying unit consists of a drying chamber, a desublimator, a vacuum pump, a cooling machine, and a regulation and measurement system.

Two infrared lamps of the KGT 220 brand were used as sources of heat in the installation. Since the chamber volume is relatively small (36 liters), two sources are sufficient to ensure uniform heating of the dried product.

The design of the vacuum chamber provides for the possibility of changing the distance between the heaters and the tray on which the product is located during the drying process. Cylindrical walls of the vacuum chamber itself serve as screens to increase the amount of radiant flux incident on the product.

The product is heated by pulses of infrared radiation to the desired temperature. Characteristic features of infrared lamps are low thermal inertia. This characteristic allows you to accurately maintain the required temperature of the product in the process of vacuum drying.

In the lower part of the chamber, there is a pipeline connecting the drying chamber with the desublimator. The desublimator is a shell-coil heat exchanger with in-line boiling of the refrigerant, which is the evaporator of the refrigerating machine. Desublimator is designed to remove water vapor from the vacuum chamber formed during the drying process. At the bottom of the desublimator,

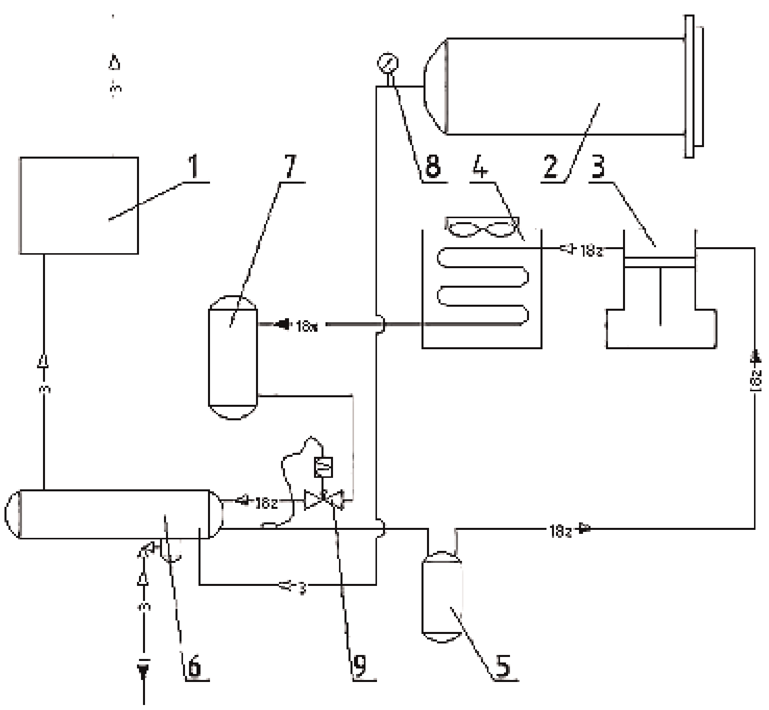

Figure 1.
The scheme of the experimental setup: (1) vacuum pump, (2) chamber vacuum, (3) compressor, (4) capacitor, (5) liquid separator, (6) desublimator, (7) receiver, (8) vacuum gauge, and (9) thermostatic valve.

there is a valve for depressurizing the system and removing the moisture frozen on the evaporator upon completion of the drying process.

The vacuum in the system is maintained using a two-stage vacuum pump brand 2TW-1C. Evaporation of evaporated moisture and non-condensable gases occurs as follows: evaporated moisture from the product enters the desublimator through the pipeline, where it passes through the evaporator and freezes on its surface that portion of water vapor that is not frozen and the non-condensable gases are pumped out with a vacuum pump into the environment.

The content of the mass fraction of moisture in the cheeses before and after drying was determined by an accelerated method on a Chizhova device, by drying the weight of the product according to GOST 3626-73.

The content of the fat mass fraction in the cheeses before and after drying was determined by the Gerber acid method according to GOST 5867-90. The method is based on the separation of fat from milk and dairy products under the action of concentrated sulfuric acid and isoamyl alcohol, followed by centrifugation and measuring the amount of released fat in the graduated part of the fat meter.

Experiments on the study of the forms and the energy of the binding of moisture in semihard cheeses were carried out using non-isothermal analysis using a derivatograph. In the course of heating the sample of the samples under study, the change in mass, the rate of change in mass, and the rate of change in temperature of the product, obtained by thermogravimetry, were determined.

Thermophysical characteristics of cheeses were determined by the first buffer method of two temperature-time intervals.

3. Results of experimental studies

Moisture is one of the most important cheese components. The moisture content of cheeses affects the ripening process, the cheese structure, and its thermophysical properties. The quantitative content of various forms and the binding energy of moisture in cheeses were determined (**Tables 2** and **3**).

It should be clarified that the mass fraction of moisture in the cheese was, for Sovetskiy, 40%; Dutch, 44%; and Ozernyiy, 48%. In the "Soviet" cheese, the highest content of bound moisture is set at 18.0%, "Dutch," 13.0%; and "Ozernyiy," 10.0%. The Sovetskiy cheese shows the smallest amount of total moisture from the three considered cheeses, while it contains the greatest amount of bound moisture. The content of energy-intensive bonds in cheeses depends on the technology of their production and the duration of the ripening process. P.F. Krasheninin and V.P. Tabachnikov established a general increase in the water-holding capacity along with the cheese maturation [5]. That is, the duration of ripening can be taken into account as a first approximation as a factor affecting

Types of cheese	Physicochemical bond		Physicomechanical bond	
	Adsorption-bound moisture		Osmotically bound moisture and microcapillary moisture	Wetting moisture and macrocapillary moisture
	Monomolecular	polymolecular		
Sovetskiy	7.0	11.0	12.0	10.0
Dutch	5.0	8.0	19.0	12.0
Ozernyiy	4.0	6.0	21.0	17.0

Table 2.
Quantitative content of various forms of moisture binding in cheese (%).

Form of the moisture binding with the matter	Types of cheese		
	Sovetskiy	Dutch	Ozernyiy
Physicochemical bound			
Monomolecular adsorption	4.20–2.70	3.90–2.50	3.40–2.50
Polymolecular adsorption	2.20–0.50	2,30–0,70	2.20–0.70
Osmotically bound	0.45–0.12	0.65–0.10	0.60–0.10
Physicomechanical bound			
Microcapillary	0.45–0.12	0.65–0.10	0.60–0.10
Wetting and macrocapillary	<0.10	<0.10	<0.10

Table 3.
Binding energy of moisture in cheese$\cdot 10^{-5}$*, J/kg.*

the amount of bound moisture in cheese: the longer the ripening process is, the more bound moisture is contained in the cheese. This dependence is quite aligned with our results.

Studies have shown that the energy characteristic of the bound moisture is different; when moving from free moisture (wetting and macrocapillaries) to bound moisture (mono- and polymolecular adsorption), the binding energy of moisture to the dry matter of the cheese increases significantly. Binding energy (10^{-5} J/kg) for wetting and macrocapillary moisture, it is <0.10, for osmotically bound moisture and moisture of microcapillaries 0.45–0.12, for polymolecular adsorption moisture 2.30–0.50, and for moisture monomolecular adsorption 4.20–2.50. Consequently, the moisture of the monomolecular and polymolecular adsorption due to the highest binding energy is the most strongly bounded. In this regard, it can be said that the moisture of monomolecular adsorption is the main hydration indicator of the product constituent parts and is important for the food restoration after drying.

It is known that while storage, dry food products absorb moisture from the ambient air until an equilibrium state occurs. The works of R.I. Ramanauskas are devoted to the study of the equilibrium moisture content of dairy products [6, 7].

We have conducted studies of the cheese hygroscopic characteristics (**Table 4**).

When the air relative humidity decreases, the equilibrium moisture of the product decreases too, while the binding energy of moisture with the dry part of the product increases.

Table 5 shows data on the thermal characteristics of cheese. To determine the mode of drying for any product, including cheese, it is necessary to know both physicochemical parameters and thermophysical characteristics. The latter characteristics are necessary in the determination of regime parameters and technological ones as well. When choosing regime parameters (temperature, heat flux density, and residual pressure), it is important to take into account the product's heat capacity and thermal diffusivity in order to calculate the temperature distribution over the layer thickness and the rate of its change. In determining the technological parameters (thickness of the drying layer and the degree of grinding), the thermal conductivity should be observed, since the thickness of the layer of dried material depends on its size.

To determine the effect of moisture content in cheese on its cryoscopic temperature, samples of "Dutch," "Kostromskoy," and "Poshekhonskiy" cheese with a pH of 5.7 and a moisture content of 38–45% were used. **Figure 2** shows the dependences of the change in the cryoscopic temperature of semihard cheeses with a low second heating temperature on the mass fraction of moisture.

Relative air humidity (%)	10	20	30	40	50	60	70	80	90
Sovetskiy cheese									
Equilibrium humidity (%)	7.0	10.0	11.5	13.5	15.5	17.5	19.5	22.0	26.5
Dutch cheese									
Equilibrium humidity (%)	5.0	6.5	8.0	9.5	11.0	13.0	17.0	25.0	33.0
Ozernyiy cheese									
Equilibrium humidity (%)	4.0	5.0	6.0	7.0	8.0	10.0	15.0	22.0	31.0

Table 4.
Hygroscopic characteristics of cheeses.

Types of cheese	Thermophysical characteristics			
	Density (kg/m^3)	Thermal conductivity (W/(m·K))	Heat capacity (J/(kg·K))	Thermal diffusivity (10^{-6} m^2/c)
Sovetskiy	1070	0.34	2570	0.135
Dutch	1060	0.35	2530	0.133
Ozernyiy	1040	0.35	2540	0.132

Table 5.
Cheese thermophysical characteristics.

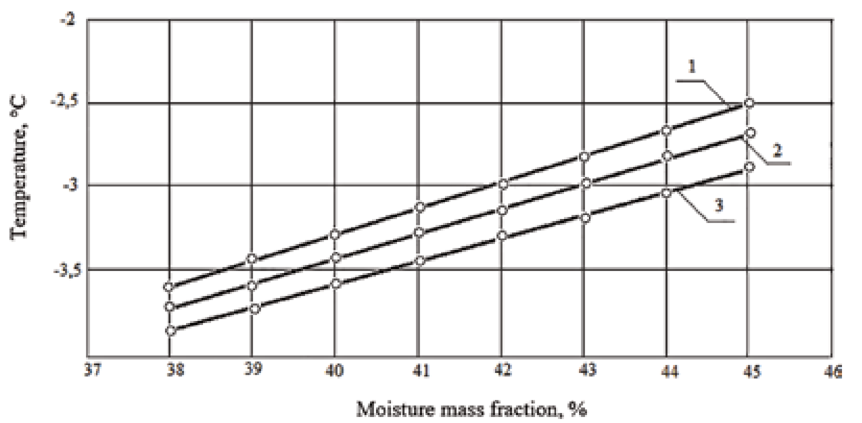

Figure 2.
Dependence of the cryoscopic temperature of cheeses on the mass fraction of moisture: (1) "Dutch," (2) Kostromskoy, and (3) "Poshekhonskiy."

As a result of the research, the dependences between the cryoscopic temperature $t_{кр}$ and the moisture content in hard cheeses with a low second heating temperature were revealed for:

"Dutch" cheese:

$$t_{кр} = 0{,}1595 \cdot B_c - 9{,}67 \quad (1)$$

"Kostromskoy" cheese:

$$t_{кр} = 0{,}1464 \cdot B_c - 9{,}28 \quad (2)$$

"Poshekhonskiy" cheese:

$$t_{кр} = 0{,}12 \cdot B_c - 8{,}38 \quad (3)$$

where B_c is the mass fraction of moisture in the cheese.

According to **Figure 2** and Eqs. (1)–(3), it follows that a change in moisture of 1% leads to a change in the cryoscopic temperature of the studied cheeses by 0.25°C.

The kinetics of the drying process is usually understood as a change in the average volume of the dried material humidity φ_c and temperature t over time τ. The nature of the drying process is most accurately described by the drying curves (in the coordinates of the moisture mass fraction-time), the curves of the drying speed (in the coordinates of the drying speed-the moisture mass fraction), and temperature curves (in the coordinates of the material temperature-the humidity of the material). The work of drying units of different performances cannot be compared by changing the mass of material in the drying process. To do this, it is rational to use graphic figures of the change in moisture mass fraction of the material over time $(\varphi - \tau)$—drying curves.

The data for constructing the curves is usually obtained in the laboratory when the mass (weight) of the material sample and its temperature are recorded during the drying process. Drying is usually done with heated air at a constant rate. For vacuum drying, the constant mode is the material temperature, the residual pressure value. Naturally, the transfer of laboratory research data to production conditions (where drying is usually carried out under variable conditions) requires special adjustments. The change in the average volume moisture mass fraction over time $\varphi_c = f(\tau)$ is graphically represented by a curve called the drying curve. In the general, the drying curve consists of several sections corresponding to different periods of drying [6]. **Figure 3** shows the curves of vacuum drying (heat load-time, temperature–time, mass fraction of moisture-time) for the "Swiss" cheese.

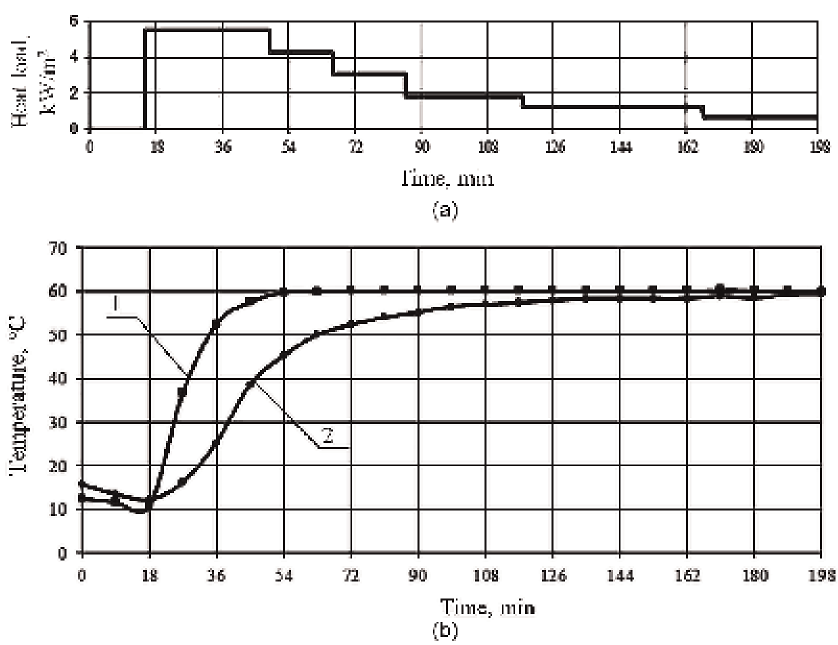

Figure 3.
Drying curves for "Swiss" cheese. (a) Heat load. (b) Temperature on the surface and throughout the thickness: mode: t = 60°C, q = 5.52 kW/m², P = 2–3 kPa, and h = 10 mm. (1) On the surface. (2) Throughout the thickness.

Within 9–15 min, until the drying unit reached the required mode by residual pressure (2–3 kPa), heat is not supplied from the heaters (**Figure 3**), and the cheese temperature decreases from 17 to 15 to 12–10°C.

The temperature lowers due to the intense evaporation of moisture from the surface of the cheese. The decrease in the mass fraction of moisture while the unit is set to operate is 2–3%. Segment A–B corresponds to the time required for the unit to reach the required mode by residual pressure (2–3 kPa). Then comes the first drying period—a period of constant drying rate, a segment B–K1 on the curve of change in the mass fraction of moisture. The first period is characterized by a constant rate of decrease in the mass fraction of moisture (for equal periods of time, the same amount of moisture is removed).

The temperature of the cheese increases due to the supply of heat from the heaters. The cheese temperature during the first period reaches the desired value and is maintained at a predetermined level (**Figure 3**). By the end of the first period, the temperature leveling along the thicker layer of the dried cheese is observed. At the beginning of the first period, the heat load is equal to the maximum allowable value. When the cheese reaches the desired drying temperature, the heat load is reduced. Reducing the heat load is necessary to prevent the drying temperature of the cheese from exceeding the required value.

During the first period, the greatest amount of moisture is removed. In the first drying period, the moisture mass fraction of the "Swiss" cheese decreased by 24%; "Dutch," 23%; and "Poshekhonskiy," 34%. The duration of the first drying period is, for the "Swiss" cheese, 74 min; "Dutch," 83 min; "Kostromskoy," 92 min; and "Poshekhonskiy," 80 min. The period of constant drying speed continues until the first critical moisture content reaches.

During the period of constant drying rate, the intensity of the process is determined only by the parameters of the drying agent and does not depend on the moisture content (mass fraction of moisture) and the physicochemical properties of the material. At a certain value of the moisture mass fraction, the rate of the moisture removal begins to decrease and the second period starts—the period of falling drying rate. The beginning of the second period corresponds to the critical moisture content of the material. During the second period, the moisture that is the most strongly bound to the product is removed. The evaporation rate decreases, the drying rate slows down, and the temperature levels throughout the product thicken.

In the period of the falling drying rate, the drying rate decreases with decreasing moisture content of the material. During this period, the bound moisture is removed, and a gradual decrease in the drying rate is explained by an increase in the binding energy of moisture with the material.

In the period of falling speed of drying, the mass fraction of moisture of the "Swiss" cheese decreases by 12%; "Dutch," 15%; "Kostromskoy," 24%; and "Poshekhonskiy," 12%. The duration of the period of the falling speed of drying "Swiss" cheese is 108 min; "Dutch," 100 min; "Kostromskoy," 17 min; and "Poshekhonskiy," 100 min.

Duration of the period of the falling drying speed can be divided into some segments corresponding to the first and second phases. By the second critical moment, the evaporation zone reaches the deep layers of the product. At this moment, movement of moisture occurs only in the form of steam, and mainly adsorption moisture evaporates.

At the end of the drying process, the drying curve (the curve of change in the mass fraction of moisture) asymptotically approaches the equilibrium moisture, and the equilibrium moisture value corresponds to this drying mode. When equilibrium moisture occurs, the drying process stops—the drying rate equals zero.

The first derivative of the function $\varphi_c = f(\tau)$ calculates the drying rate, under which we understand the change in the material moisture content per unit time ($d\varphi_c/d\tau$, %/мин). Curves of drying rates were drawn by the method of graphical differentiation according to drying curves (curves of change in the mass fraction of moisture): the drying rate at a given time is determined as the tangent of the tangent angle, drawn through the drying curve point that corresponds to a specific moisture mass fraction:

$$tg\psi = \frac{d\varphi}{d\tau}. \tag{4}$$

Maximum drying rate *N* during the period of constant drying rate:

$$tg\psi = \left(\frac{d\varphi}{d\tau}\right)_{МАКС} = N, \text{ \%/чили\%/мин}. \tag{5}$$

By the end of the process at equilibrium moisture, the drying rate is $\frac{d\varphi}{d\tau} = 0$.

At the beginning of the drying process, the unit goes to the desired mode for the residual pressure, and the drying rate increases from zero to the maximum value. The maximum value of the cheese drying rate for "Swiss" is 0.62%/min; "Dutch," 0.71%/min; "Kostromskoy," 0.88%/min; "Poshekhonskiy," 0.78%/min; "Rizhskiy," 0.92%/min; and "Russian," 0.75%/min.

In the period of constant drying rate, the drying rate is equal to the maximum. During the constant period of drying, moisture is removed from the cheeses: "Swiss," 18%; "Dutch," 17%; "Kostromskoy," 22%; "Poshekhonskiy," 28%; "Rizhskiy," 48%; and "Russian," 32%.

Starting from the first critical point, a decrease in the drying rate begins. The nature of the curves in the period of the falling drying rate corresponds to colloidal capillary-porous bodies.

Critical humidity corresponds to the humidity limit when the mechanism of moisture movement in the material changes. This point marks the beginning of moisture removal by polymolecular adsorption.

The second critical point corresponds to the following mass fraction of moisture of cheese: "Swiss," 10%; "Dutch," 10%; "Kostromskoy," 13%; "Poshekhonskiy," 8%; "Rizhskiy," 10%; and "Russian," 9%. Moisture mass fraction of dry cheeses is 4–5%. The difference between the mass fraction of moisture at the second critical point and the mass fraction of moisture of dry cheeses is the moisture of polymolecular adsorption. That is, the mass fraction of moisture of polymolecular adsorption for cheeses is 4–9%.

Temperature curves $t = f(\varphi_c)$ are very informative. Temperature curves for the first were introduced by A.V. Lykov; now, they are important for the analysis of the drying process. **Figure 4** shows the temperature curves characteristic of vacuum drying of Swiss cheese.

At the beginning of the drying process, the cheese temperature decreases as the heat from the heaters is not supplied. At the beginning of the first drying period, when the heaters are turned on, the surface temperature of the material rises, reaching the temperature of the wet-bulb thermometer. During this period, the most intense moisture return occurs, and practically all the heat imparted to the material is spent on the moisture evaporation. The temperature over the thicker layer of cheese is equalized by the end of the first drying period.

Starting from the first critical point, the rate of moisture evaporation decreases. When the humidity of the cheeses reaches the value of the equilibrium moisture, the drying process is completed. The equilibrium moisture content for

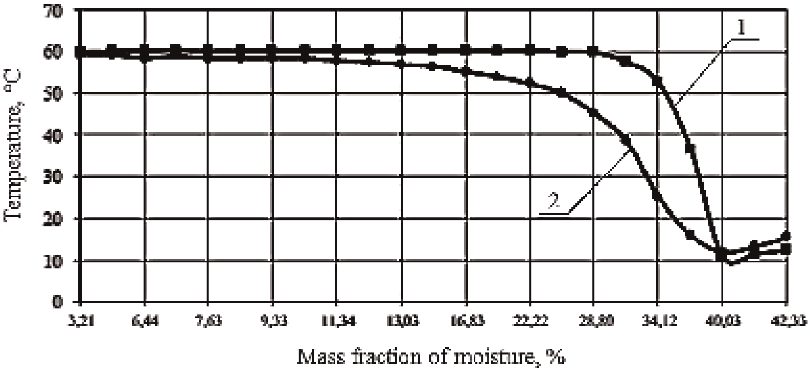

Figure 4.
Temperature curves of vacuum drying of Swiss cheese: (1) on the surface and (2) in the thickness.

cheeses is, for "Swiss," 5.21%; "Dutch," 4.46%; "Kostromskoy," 5.46%; and "Poshekhonskiy," 4.26%.

It has been established that vacuum drying of cheeses proceeds in two periods: constant and falling drying rates. The drying curves of various types of cheeses in the coordinates were obtained and investigated (heat load-time, temperature–time, mass fraction of moisture-time). By graphic differentiation, the curves of drying rate of cheeses are constructed. By the analytical method, it was determined that the amount of moisture of polymolecular adsorption for cheeses is 4–9%. The temperature curves of the cheeses in the coordinates (temperature-mass fraction of moisture) were investigated. The values of equilibrium moisture for vacuum drying of cheeses are established.

The size and volume of most materials are reduced during the drying process. This phenomenon is called material shrinkage [8–10]. For example, in convective drying, such materials as vegetables, fruits, and cereals shrink significantly, decreasing in volume by three to four times [11].

Most materials (peat, grain, leather, dough, bread, etc.) shrink throughout the drying process. However, a number of materials (clay, ceramic masses, and some other materials) shrink during a period of constant drying rate. In this case, the shrinkage is stopped at approximately critical moisture content, if the moisture content gradient inside the material is small. Other materials (wood, coal) shrink only in the period of falling drying rate, it begins approximately at a point of critical moisture content [12].

The least shrinkage results are shown by cheeses produced with a residual pressure of 2–3 kPa. It is established that an increase in the size of grinding and thickness of the drying layer of the "Dutch," "Kostromskoy," and "Poshekhonskiy" cheeses leads to an increase in shrinkage factors. At the drying material thickness from 10 to 30 mm, the shrinkage ratio is from 3 to 14%. When the thickness of the drying layer is 40 mm, the coefficient of shrinkage increases up to 15–24%. Drying the cheeses with the required operating and technological parameters causes minimal drops in the mass fraction of moisture, while particle shrinkage is minimal and takes place with preservation of shape.

Figure 5 shows the dependence of the coefficient of cheese shrinkage on the initial mass fraction of moisture.

With an increase in the mass fraction of the cheese moisture, the shrinkage factors increase. The greatest increase in the coefficient of cheese shrinkage is observed when the mass fraction of moisture is more than 50%. With a change in the mass fraction of the cheese moisture from 40 to 50%, the shrinkage rate increases by 2.5%; from 50 to 60%—by 6.5%.

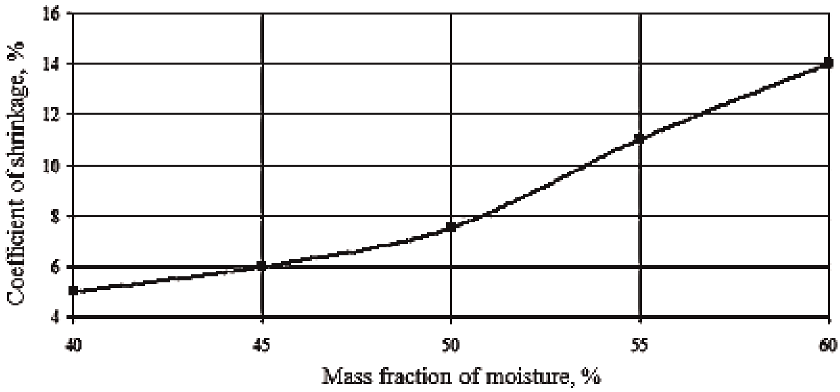

Figure 5.
The dependence of coefficients of cheeses shrinkage on the mass fraction of moisture.

Figure 6 shows the dependence of the shrinkage factor on the initial mass fraction of the cheese moisture in the drying process. According to the curves presented in **Figure 5**, the following dependence is established: with an increase in the mass fraction of cheese moisture, the shrinkage rate increases. A similar dependence follows from the analysis of the curves presented in **Figure 6**. Shrinkage of cheeses in both periods of vacuum drying occurs evenly.

If the linear size of the material (length, width, height) is denoted with l, when the mass fraction of moisture is W, then it can be written as [13]

$$l = l_0 \cdot (1 + \beta_l \cdot W) \tag{6}$$

where l_0 is the linear size of the absolutely dry material;

β_l is a coefficient of linear shrinkage, characterizing shrinkage rate of 1%, i.e., $\beta_l = \frac{1}{l_0} \cdot \frac{dl}{dW}$.

Formula (6) is valid for relatively small gradients of moisture content inside the material. With a large moisture content gradient, the surface layers of the material will shrink faster than the average ones. **Table 6** shows the moisture content of the "Sovietskiy" and "Dutch" cheese in a layer thickness of 20 mm.

The moisture content data on the thickness of the cheese layer was obtained at the required temperatures, thermal loads, and residual pressure of the vacuum drying of the cheeses. As the temperature increases, the heat load on the surface of the cheese

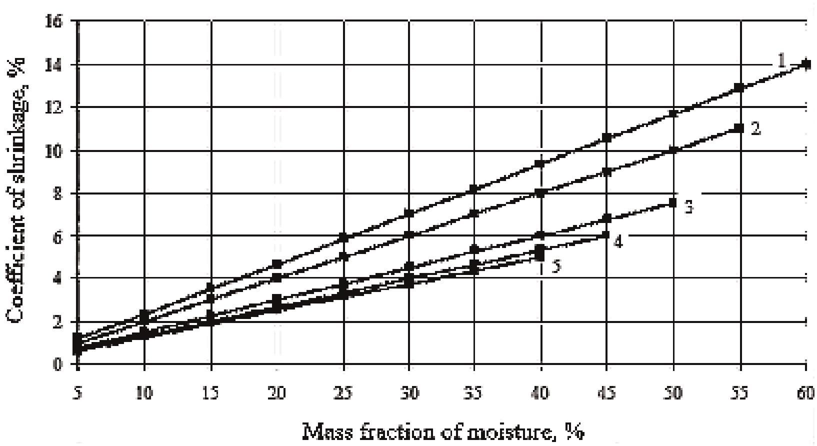

Figure 6.
The dependence of shrinkage coefficients of cheeses on the initial mass fraction of moisture.

moisture content decreases rapidly, while in the thickness layers, it changes more slowly. Surface layers, which affect the size of the material, tend to decrease not in proportion to the average moisture content, but approximately in proportion to the moisture content on the surface. Therefore, starting from a certain moisture content (mass fraction of moisture), shrinkage is hardly observed (**Figure 7**).

The shrinkage curves of the cheeses, "Sovietskiy" (1) and "Dutch" (3), were obtained at the required drying temperature of 60°C. Shrinkage curves 2 and 4 were obtained at a temperature higher than the required one (80°C). When the drying temperature is high, the surface layers dry quickly. The central layers have an increased mass fraction of moisture. Shrinkage at elevated temperatures is less, but dry cheese has a large mass fraction of moisture.

With an increase in the drying temperature, the shrinkage coefficient decreases; this is explained by an increase in the gradient of the mass fraction of moisture inside the material. In the presence of a gradient of the mass fraction of moisture, the surface layers tend to shrink more compared to internal ones. However, the reduction of the surface layers is impeded by internal ones, the mass fraction of which is more moisture than the surface layers. As a result, the shrinkage of the surface layers is less than that which should correspond to the moisture removed from them. Consequently, an increase in the difference in the mass fraction of moisture between the inner and surface layers is accompanied by an increase in the difference between the actual shrinkage and the possible shrinkage corresponding to the amount of liquid to be removed.

Cheese	Moisture content (wet/dry material)			
	At the first critical point		At the second critical point	
	Surface layers	Thickness layer	Surface layers	Thickness layer
Sovietskiy	6–9	20–24	4–5	9–17
Dutch	6–8	19–22	4–5	7–12

Table 6.
Moisture content of cheeses at the layer thickness of 20 mm.

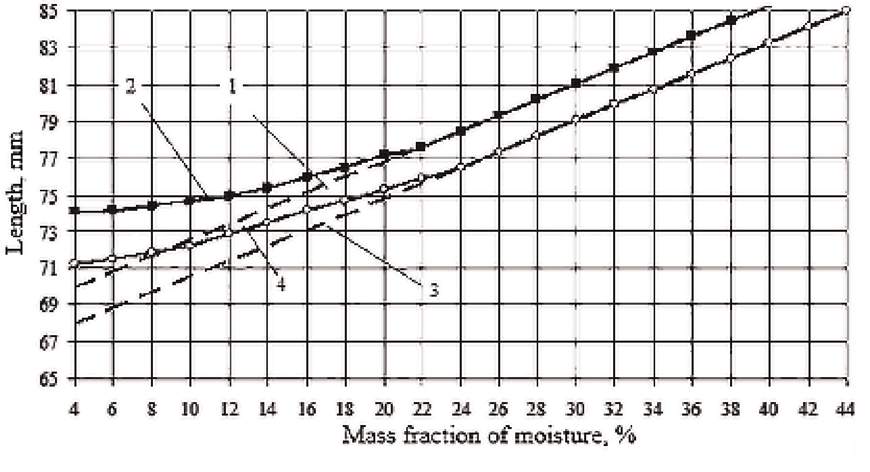

Figure 7.
Shrinkage curves of cheeses "Sovietskiy" (1 and 2) and "Dutch" (3 and 4): (1) t = 60°C; q = 5.52 kW/m²; P = 2–3 kPa; (2) t = 80°C; q = 5.52 kW/m²; P = 2–3 kPa; (3) t = 60°C; q = 7.36 kW/m²; P = 2–3 kPa; (4) t = 80°C; q = 7.36 kW/m²; P = 2–3 kPa.

Thus, formula (6) is valid only with a small gradient of moisture content (mass fraction of moisture), when the mass fraction of moisture u at any point of the cheese is approximately equal to the average mass fraction of moisture $W(u \sim W)$. A more rigorous writing of the formula (4.6) was proposed by A.V. Lykov [14, 15]:

$$l = l_0 \cdot (1 + \beta_l \cdot W). \tag{7}$$

For most materials, the dependence between the volume of the body and its moisture content is linear:

$$V = V_0 \cdot (1 + \beta_V \cdot W), \tag{8}$$

where

β_V is the coefficient of volumetric shrinkage, equal to the relative decrease in volume when moisture content changes on 1%, $\beta_V = \frac{dV}{V_0 \cdot dW}$.

V_0 is the volume of absolutely dry matter.

A.V. Lykov proposed to determine the coefficient β_V by two values V_1 and V_2 for the mass fraction of moisture and, for example, before and after drying. Consequently:

$$V_1 = V_0 \cdot (1 + \beta_V \cdot W_1), \tag{9}$$

$$V_2 = V_0 \cdot (1 + \beta_V \cdot W_2). \tag{10}$$

V_0 and β_V can be determined by these equations. Denoting relative shrinkage (with respect to the original volume) with δ, it is as

then

$$\delta = \frac{V_1 - V_2}{V_1}, \tag{11}$$

$$\beta_V = \frac{\delta}{(W_1 - W_2) - \delta \cdot W_1}. \tag{12}$$

Table 7 shows the coefficients of volumetric shrinkage of cheeses.

If the linear sizes of the cheeses vary from the mass fraction of moisture according to the ratio (7), a simple relationship can be found between β_V and β_l, as well as between β_l and β_S.

The area of the sample material is equal to the product of the length l by the width L, that is:

$$S = l \cdot L = l_0 \cdot L_0 \cdot (1 + \beta_l \cdot W)^2 = S_0 \cdot (1 + \beta_l \cdot W)^2, \tag{13}$$

where $S_0 = l_0 \cdot L_0$ is the area of absolutely dry material.

Cheese	Coefficient of volumetric shrinkage (β_V)
Sovietskiy	0.017–0.004
Dutch	0.006–0.003

Table 7.
The coefficients of volumetric shrinkage of cheeses.

In deriving Eq. (13), it is assumed that the material is isotropic and shrinkage along the length and width is the same. If $(1 + \beta_l \cdot W)^2$ expanded in a row, the value of $\beta_l^2 \cdot W^2$ is small compared to $2 \cdot \beta_l \cdot W$; then, it can be written as

$$S = S_0 \cdot (1 + 2 \cdot \beta_l \cdot W) = S_0 \cdot (1 + \beta_S \cdot W), \tag{14}$$

where $\beta_S = 2 \cdot \beta_l$ is the coefficient of shrinkage on the area; it equals to twice the linear shrinkage coefficient.

The coefficient of shrinkage on the area can be determined by the formula:

$$\beta_S = \frac{\delta_S}{(W_1 - W_2) - \delta_S \cdot W_1}, \tag{15}$$

where $\delta_S = \frac{(S_2 - S_1)}{S_1}$ is the relative shrinkage on the area.

The dependence between the volume of the material and the moisture content is written as

$$V = V_0 \cdot (1 + \beta_V \cdot W)^3. \tag{16}$$

Thus, an approximate formula can be derived:

$$V = V_0 \cdot (1 + 3 \cdot \beta_V \cdot W) = V_0 \cdot (1 + \beta_V \cdot W), \tag{17}$$

where $\beta_V = 3 \cdot \beta_l$ is the coefficient of volumetric shrinkage, equal to triple linear shrinkage coefficient.

Thus, the dependences of the coefficients of cheese shrinkage on the thickness of the drying layer and the shape and size of grinding are obtained. When the thickness of the drying layer is from 10 to 30 mm, the coefficient of cheese shrinkage is from 3 to 14%, depending on the shape and size of the grinding. With an increase in the mass fraction of the moisture of the cheeses, the shrinkage coefficient increases. It was determined that the shrinkage of cheeses in both periods of vacuum drying occurs uniformly. When the drying temperature rises above the required shrinkage ratio decrease, this is explained by the increase in the gradient of the mass fraction of moisture inside the material.

Shrinking of wet material with a uniform distribution of moisture content and temperature is a physical property of the material, when fluid is removed from it and does not cause any dangerous stresses. Only shrinkage of the material with an uneven distribution of moisture content causes a stress state, which can lead to the appearance of cracks and the complete destruction of the body structure. Therefore, the main obstacle to the rapid drying of many materials is their cracking. The cause of the cracking appearance (local destruction), as well as complete destruction (loss of the integrity of the structure), is the development of the volume-stressed state of the material being dried beyond the maximum allowable, due to the strength of the material.

This stress state is created by unacceptable shrinkage, which, in turn, appears as a result of an uneven distribution of moisture content and temperature inside the material [16, 17].

The method of studying shrinkage stresses does not exclude a phenomenological approach to the phenomenon of shrinkage of wet material under study. It is important to note that the capillary and wedging pressures of the liquid phase in a solid body are functions of moisture content. Therefore, the field of capillary contractions under isothermal conditions will be similar to the field of moisture content.

It follows that the uneven distribution of moisture content (moisture content field) is the main characteristic of the volume-stressed state of a moist body when it is dried.

A similar picture occurs when studying thermal stresses. The phenomenological approach consists in the fact that the body-stressed state of the body at heating is uniquely determined by an uneven temperature distribution (temperature field). The main cause of cracking in the drying process is the presence of moisture content and temperature fields with a significant difference in these values.

A.V. Lykov considered drying the material in the form of a plate. Evaporation occurs from two opposite sides (the remaining surfaces have moisture insulation, that is, the moisture content surface is one-dimensional), and the temperature is the same everywhere and constant (isothermal drying conditions in the first period). It has been determined that the maximum compressive stresses occur in the central plane ($u_ц = u_{макс}$) and the maximum tensile stresses appear on the surface ($u_n = u_{мин} < \overline{u}$) when the linear strain modulus E remains unchanged.

During the period of constant drying rate, the moisture content is distributed according to the law of a parabola. This distribution does not occur immediately, but after a certain period of time. Then, the difference between the average moisture content $\overline{u}$ and the moisture content on the surface u_n equals to

$$\overline{u} - u_n = \frac{2}{3} \cdot \Delta u = -\frac{R}{3} \cdot (\forall u)_n, \tag{18}$$

where $\Delta u_n = u_ц - u_n$ is the moisture content difference between the central layers and surface.

$(\forall u)_n$ is the moisture content gradient on the plate surface.

$2 \cdot R$ is the plate thickness.

The tensile stress on the surface of the plate is [18]

$$P_n = -\frac{2}{3} \cdot \frac{\beta_l \cdot E \cdot \Delta u}{(1 + \beta_l \cdot u_n) \cdot (1 - \mu)} = \frac{\beta_l \cdot E \cdot R}{3 \cdot (1 - \mu) \cdot (1 + \beta_l \cdot u_n)} \cdot (\forall u)_n. \tag{19}$$

According to the formula, it follows that, if the value is $\Delta u_n = u_ц - u_n$, the cracking of the drying material occurs when its strength is less than the value of P_n. Experiments on vacuum drying of raw materials confirm that cracking occurs at a certain value of $(\Delta u)_{макс}$.

Dry cheeses are an indispensable product for diet food, supply of remote areas, army, and expeditions. In addition, the product is necessary for the production of modern nutrient mixtures for a given purpose (dry breakfasts, mixtures of medical nutrition). Dry cheese can be used as a base for various foods and sauces. Cheese-based sauces can be used instead of mayonnaise, which can significantly expand the possibilities of their use in cooking. After reconstitution, the dry cheese is vacuum dried and has the consistency of melted cheese.

The obtained research results can be successfully applied in the food industry not only to cheeses but also to other products. They are of theoretical and practical value and can be used by technologists, researchers, and food industry workers in the development of relevant technological processes.

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References

[1] King V, Zall R. Controlled low-temperature vacuum dehydration—A new approach for low-temperature and low-pressure food drying. Journal of Food Science. 1989;**54**(6):1573-1579

[2] Ermolaev VA. Development of technology of vacuum drying of fat-free cottage cheese[Ph.D. thesis in Engineering Science]. Kemerovo Technological Institute of Food Industry. Разработка технологии вакуумной сушки обезжиренного творога: диссертация кандидата технических наук. Кемеровский технологический институт пищевой промышленности. 168; 2008

[3] Devahastin S, Suvarnakuta P, Soponronnarit S, Mujumdar A. Comparative study of low-pressure superheated steam and vacuum drying of a heat-sensitive material. Drying Technology. 2004;**22**:1845-1867

[4] Ermolaev VA. Kinetics of the vacuum drying of cheeses. Foods and Raw Materials. 2014;**2**(2):130-139

[5] Lope J, Vega-Galvez A, Bilbao-Sainz C, Bor-Sen C, Uribe E, Quispe-Fuentes I. Influence of vacuum drying temperature on: Physico-chemical composition and antioxidant properties of murta berries. Journal of Food Process Engineering. 2017;**40**(6):e12569

[6] Xie L, Mujumdar AS, Xiao-Ming F, Jun W, Jian-Wu D, Zhi-Long D, et al. Far-infrared radiation heating assisted pulsed vacuum drying (FIR-PVD) of wolfberry (*Lycium barbarum* L.): Effects on drying kinetics and quality attributes. Food and Bioproducts Processing. 2017;**102**:320-331

[7] Rabeta M, Lin S. Effects of different drying methods on the antioxidant activities of leaves and berries of *Cayratia trifolia*. Sains Malaysiana. 2015; **44**(2):275-280

[8] Rubinskienė M, Viškelis P, Dambrauskienė E, Viškelis J, Karklelienė R. Effect of drying methods of the chemical composition and colour of peppermint (*Mentha* × *piperita* L.) leaves. Zemdirbyste-Agriculture. 2015; **102**(2):223-228

[9] Zdravko M, Aleksandra N, Stela D, Radomir V. Optimization of frozen wild blueberry vacuum drying process. Hemijska Industrija. 2015;**69**(1):77-84

[10] Wojdylo A, Figiel A, Lech K, Nowicka P, Oszmianski J. Effects of convective and vacuum- microwave drying on the bioactive compounds, color, and antioxidant capacity of sour cherries. Food and Bioprocess Technology. 2014;**7**:829-841

[11] Yanqiu M, Xinhuai Z, Bingxin L, Chenghai L, Zheng X. Influences of microwave vacuum puffing conditions on anthocyanin content of raspberry snack. International Journal of Agricultural and Biological Engineering. 2013;**6**(3):80-87

[12] Horszwald A, Julien H, Andlauer W. Characterisation of *Aronia* powders obtained by different drying processes. Food Chemistry. 2013;**141**(3):2858-2863

[13] Li Y-h, Qi Y-r, Wu Z-f, Wang Y-q, Wang X-c, Wang F, et al. Comparative study of microwave-vacuum and vacuum drying on the drying characteristics, dissolution, physicochemical properties, and antioxidant capacity of *Scutellaria* extract powder. Powder Technology. 2017;**317**:430-437

[14] Ermolaev VA. Effect of vacuum drying on microstructure of semi-solid cheese. Foods and Raw Materials. 2014; **2**(1):11-16

[15] Nile S, Park S. Edible berries: Bioactive components and their effect

on human health. Nutrition. 2014;**30**(2): 134-144

[16] Kellogg J, Wang J, Flint C, Lila M, Ribnicky D, Kuhn P, et al. Alaskan wild berry resources and human health under the cloud of climate change. Journal of Agricultural and Food Chemistry. 2010; **58**(7):3884-3900

[17] Bowen-Forbes C, Nair M, Zhang Y. Anthocyanin content, antioxidant, anti-inflammatory and anticancer properties of blackberry and raspberry fruits. Journal of Food Composition and Analysis. 2010;**23**(6):554-560

[18] Afrin S, Gasparrini M, Forbes-Hernandez T, Reboredo-Rodriguez P, Giampieri F, Battino M, et al. Promising health benefits of the strawberry: A focus on clinical studies. Journal of Agricultural and Food Chemistry. 2016; **64**(22):4435-4449

Chapter 3

Milk By-Products Utilization

Syed Mansha Rafiq and Syed Insha Rafiq

Abstract

The dairy industry processes raw milk into an array of products including butter, cheese, cream, yogurt, ghee, condensed milk, dried milk, ice cream, etc. and produces various by-products including buttermilk, whey, ghee, and skim milk. These dairy by-products have high nutritive value and have found applications in many food industries as well as nonfood applications. Buttermilk which is a by-product of butter-making is used both in liquid form (fermented to produce a beverage *chaas*) and dried to be used as an ingredient. Whey, a by-product of cheese and paneer manufacture with high nutritive value, has been utilized in the preparation of products like sports drinks and beverages. Whey is also used in the preparation of certain types of cheese like ricotta. Skim milk which is a by-product of cream manufacture has been used to produce flavored milks and certain type of cheeses like cottage and quark cheese. Ghee residue from ghee manufacture has been used in the preparation of sweets, cookies, and chocolates. Casein and casein derivates are mainly used in bakery and confectionary. In addition to these food applications, whey proteins (WP) and caseins have found applications as packaging films.

Keywords: buttermilk, whey, ghee residue, skim milk, caseins

1. Introduction

A number of by-products like whey, buttermilk, skim milk, and ghee residue (GR) and derived by-products like caseins, caseinates, lactose, whey proteins (WP), etc. are produced by the dairy industry. Attempts have been made globally to utilize these by-products because of their high nutritive value. Dairy plants in India are still confronted with the problem of by-product utilization because of lack of adequate technology and high cost of new technologies. However the Indian dairy industry is making advancement in this direction. Whey is the major by-product of the dairy industry. It is a useful resource of nutrients containing about 50% of the solids of milk [1]. Whey production is steadily growing, and its high organic content is an important environmental and health issue. Therefore, suitable management of this by-product is required. Like milk, whey may have different origins (e.g., goat, sheep, and buffalo), but the most relevant in terms of production volume and economical value is that obtained from cow milk processing. Skim milk is a by-product obtained from cream manufacture. It is rich in SNF content and has high nutritional value and has been utilized in the manufacture of a number of dairy products or in powder form. Buttermilk, a by-product of butter manufacture, has been used as such or in dried form. Ghee residue from ghee manufacture has also found applications in many food products.

2. Whey utilization

Whey, a by-product of cheese manufacturing, contains approximately 7% dry matter of which 13% is proteins. It generally represents a volume fraction of 90% in milk and is being classified into sweet and acid whey. The sweet whey originates from cheese manufacturing or from industrial casein production where the casein is coagulated by rennet, at pH of 6.0–6.5, while the acid whey (pH < 5.0), resulting from processes in which casein is coagulated by fermentation or addition of organic or mineral acids, as in the processing of fresh, acid-coagulated cheeses (e.g., cottage cheese or quark) or strained yogurt (e.g., Greek-style yogurt). The main components for both types of wheys are given in **Table 1**. Water constitutes approximately 93% of the whey, while the total solid fraction contains lactose (70–72%), minerals (12–15%), and whey proteins (8–10%). The main difference between both wheys is the mineral content, the acidity, and the composition of the whey protein fraction. Acid whey has higher calcium content as, at this low pH, the colloidal calcium contained in the casein micelles in normal milk solubilized and partitioned into the whey [2]. Composition of whey protein fraction is different as sweet whey contains glycomacropeptide, a fragment of the κ-casein molecule produced by rennet clotting, constituting 20% of the whey protein fraction of sweet, rennet-based wheys [2]. Acid whey has a large potential to be used as the main component of beverages because of its nutritional composition. The utilization of liquid acid whey offers an interesting approach as there is no need for using complex technology other than pasteurization.

Up until very recently, whey resulting from the curd during manufacture of cheese was regarded as a polluting effluent from the dairy industry. Nowadays, the potential of a vast range of whey proteins and their peptides with great potential health benefits is well known. Recently, whey gained interest as a food ingredient, coming into use as a technological agent particularly through whey proteins, achieving a unique blend between nutritional and functional properties with applications both in food and health. Whey components are being separated by isolation and fractionation on selective porous membranes. Extensive investigations focused on the exploitation of techno functional, biological, and nutritional properties of the whey [3]. By far, membrane technology enabled the breakthrough of whey processing into several derivatives favoring their incorporation as ingredients into different foods. These whey proteins are separated and purified from the liquid whey in an efficient membrane filtration process and subsequent spray drying to obtain either whey protein concentrate (WPC) (65–80% protein in dry matter) or whey protein isolate (WPI) (90% protein in dry matter). Ultrafiltration (UF) techniques have been used for cheese milk to retain whey proteins to increase the yield of the

Component	Sweet whey (g/L)	Acid whey (g/L)
Total solids	63.0–70.0	63.0–70.0
Lactose	46.0–52.0	44.0–46.0
Protein	6.0–10.0	6.0–8.0
Calcium	0.4–0.6	1.2–1.6
Phosphate	1.0–3.0	2.0–4.5
Lactate	2	6.4
Chloride	1.1	1.1

Source: [2].

Table 1.
Typical composition of sweet and acid whey.

end product. Moreover, whey proteins have been added into cheese to boost its nutritional profile. Different pre-treatments of cheese milk have been developed to incorporate native or denatured WP in the cheese matrix. These options opened new avenues for progress in cheese-making.

Although these whey proteins are used as additives in the agro-food industry, such as the athletic drinks, still, 40% of whey remains unprocessed, which makes it an interesting resource in view of its excellent oxygen barrier properties [4, 5]. Whey protein films have excellent oxygen, aroma, and oil barrier properties. They have excellent mechanical properties that provide durability when used as coatings on food products, films separating layers of heterogeneous foods, or films formed into pouches for food ingredients. These films do not significantly compromise the desirable primary barrier and mechanical properties as packaging films and hence add value for ultimate commercial applications [6, 7]. Whey-based formulations are processed for packaging applications and edible coatings through extrusion as well as compression molding. Incorporation of plasticizing agents is necessary to overcome the intrinsic brittleness. Whey protein isolate films are fully transparent. Whey coatings with a barrier layer and an active layer have been developed. The barrier layer contains whey protein isolates supplemented with plasticizers, and the active layer contains antimicrobials or antioxidants to extend the shelf life of the packaged food. Whey-based films may improve the sensory attributes of the coated goods while providing some health benefits to the consumers. These proteins have been used as a coating on paper as well as on plastics, polypropylene (PP), polyvinylchloride (PVC), and low-density polyethylene (LDPE), which demonstrated excellent visual properties, such as excellent gloss and high transparency, as well as good mechanical properties.

3. Technologies to include whey proteins in cheese

The incorporation of whey proteins into the cheese matrix has been made possible with a number of new technologies. Whey protein addition enhances the nutritional and functional properties as well as the economic effectiveness of cheese production. Addition of whey proteins increases the yield but may result in a slightly poor flavor and texture [8]. Whey protein concentrate and whey protein powder addition has been reported in a variety of cheeses that include cream cheese, cheese spreads, Cheddar cheese, Gouda cheese, processed cheese, Domiati cheese, etc. Addition of WPC was found to increase the yields in all cheeses with softer texture in camembert and Iranian white cheese. The influence of whey protein incorporation in processed cheese on its functional and sensory properties has been extensively studied. It has been found that whey proteins can be used to replace caseins up to 2% in processed cheese [9]. Whey protein concentrates are used as fat replacers in processed cheese, and they reduce the hardness of the cheese [10]. Addition of whey proteins/carboxymethyl cellulose complex recovered from whey, corresponding to 25–75% of cheese milk weight in Domiati cheese, increased cheese yield, reduced loss of weight during pickling, and enhanced the body of cheese. Flavor intensity was not affected by the addition of whey proteins [11]. Replacement of rennet casein in part with WPC in mozzarella cheese analogue resulted in greater firmness and meltability, lower cohesiveness and fat leakage, and moderate chewiness [12].

4. Membrane separation processes

Membrane separation techniques have been largely explored by dairy industries for their effective and economic implementation. These techniques work on the basis of size and shape of molecules as well as on charge and affinity for the membrane. Among these techniques UF was the first to be exploited for cheese enrichment with WP [1, 13]. Whey proteins, which remain entrapped in the curd matrix, contribute to the enhanced yield of cheese. Rennet-curd cheeses, such as mozzarella, cottage, and Cheddar, can be manufactured by this technique [14]. The implementation of spray drying has reduced the thermal degradation of whey components, as well as the cost associated with its concentration. Membrane filtration technique employs semipermeable surfaces (membranes) with specific pore sizes, where the permeate flows through, while the retentate is blocked based on size/molecular weight. Throughout the combination of successive filtrations steps, it is possible to produce protein fractions with different compositions and degrees of purity. This technology leads to a selective concentration of proteins, which after drying is called whey protein concentrate containing about 35–80% of protein. Further purification, often conjugating other techniques as ion-exchange chromatography, allows the achievement of higher degrees of purity with residual or no lactose content and higher desalination, resulting in whey protein isolate containing at least 90% of protein. With the application of more advanced techniques, such as chromatography, partial hydrolyses, and selective precipitation combined with centrifugation and dialysis, it is yet possible to obtain pure whey protein fractions. WPI and WPC can be widely used for food applications because of higher protein and amino acid contents; low calorie, fat, and sodium contents; absence of pathogens and toxic compounds; biocompatibility and generally recognized as safe status; ready availability; and inexpensive products.

5. Ghee residue utilization

Ghee is an important constituent of Indian meal prepared using different methods. It is clarified milk fat with incomparable organoleptic properties, which make it an important ingredient in a wide variety of food applications [15]. About 30–35% of the milk produced in India (112 million tons in 2009–2010) is converted into ghee [16]. A blackish brown residue mainly the SNF part of cream was coagulated out during ghee preparation as a by-product when cream is heated is known as ghee residue. It is obtained as moist brownish sediment after molten ghee has been strained out [17]. The amount of ghee residue was found to depend upon the method of preparation of ghee. This was due to the variation of nonfatty serum constituents of the different raw materials used for the preparation of ghee. Ghee yield was higher from creamery butter method in comparison to direct cream method, whereas ghee residue content was higher in direct cream method in comparison to creamery butter method. The average yield of ghee residue was maximum (12%) in direct creamery (DC) method followed by almost the same yield in creamery butter (CB) and desi butter (DB) methods, that is, 3.7%. Ripening of cream prior to clarification reduces the yield of ghee residue [18, 19]. It is one of the largest by-products of the dairy industry and consists mainly of milk proteins and small quantity of lactose and minerals. The ghee residue has been used in food industries for making sweets, bakery products, and as a flavor enhancer [20]. An appreciable amount of GR is produced in the country which is a nutritionally rich source of proteins and nitrogenous compounds. Ghee residue has been utilized for preparing burfi by mixing it with skim milk powder (SMP), khoa, chocolate, and sugar [21]. It can be utilized for preparing coconut burfi, candies, toffees, pinni, etc. after mixing with other ingredients. The nutritious by-product should be utilized as a food supplement in a variety of foods, food spreads, soups, etc. [22]. The utilization of this by-product in the preparation of some type of candies, toffees, edible pastes, etc. was suggested about two decades ago but was not adopted commercially by the industry due to lack of awareness about its nutritive value. In general, the residue contains appreciable amounts of nutrients of milk. Ghee residue has been used in the preparation of candy, chocolate, burfi-type sweet, and bakery products.

The phospholipids of milk occur in a complex form with proteins in the fat globule membrane. When butter is heated to 120°C and above, the phospholipids are liberated from the phospholipid-protein complex and transferred to the oil phase. When the ghee-making process is kept much below 120°C, phospholipids, which remain in a complex form with proteins, will not enter ghee and, therefore, will be retained by GR. GR is a rich source of phospholipids from which phospholipids can be recovered and added to ghee. Pruthi et al. [23] described a heat-processing method for the extraction and fortification of ghee with GR phospholipids. The fortification of ghee with phospholipids at 0.1% level showed that the oxidative stability of ghee can be increased by increasing its phospholipid content either through heat treatment of GR with ghee or by the addition of solvent-extracted phospholipids from GR.

6. Buttermilk utilization

Buttermilk is a by-product of butter-making. It contains components derived both from fragments of milk fat globule membrane (MFGM), mainly consisting of proteins and neutral as well as polar lipids and all water-soluble components of cream [24]. Fortification with buttermilk is done to increase the yield provided cheese quality is unchanged. Buttermilk has high phospholipid content that has a significant function as emulsifiers in food systems and makes this dairy ingredient interesting for use as a functional ingredient [25] in an array of food products like chocolate, cheese seasonings, margarine, bread, ice cream mixes, or yogurt [26–28]. The buttermilk concentrate (BMC) rich in phospholipids has been utilized in processed cheese spread to improve its organoleptic, rheological, and functional properties [29]. The use of BMC in processed cheese spreads makes this dairy product useful as a functional food. This perspective could also bring economical income by enhancing the product yield or using low-value by-products from the dairy industry, such as buttermilk. Sweet buttermilk, condensed by heat and vacuum, supplemented at levels of 4 or 6% in regard to cheese milk improved the yield of pizza cheese with the contribution of denatured WP [30]. Kumari et al. [31] verified the effect of buttermilk as an ingredient in buffalo milk-derived chhana, an Indian-style soft cottage cheese analogue. Substitution of milk with variable proportions of sweet buttermilk (from 0 to 50%) was technologically tested in cream cheese [32]. The authors revealed that the progressive increase of buttermilk percentage was followed by increase in moisture and yield. Buttermilk has been added to reduced-fat cheese up to 40% and was found to improve the sensory scores in comparison to the control [33].

7. Skim milk

Skim milk powder for cheese-making requires adequate reconstitution and recombination techniques compared to whole milk powders, and at places where modern equipment and processing facilities for the reconstitution and recombination are not available, the use of whole milk powders could be advantageous. Addition of skim milk powder has been reported in Karish cheese, Domiati cheese, and processed cheese. Skim milk along with milk protein and stabilizers were used to produce high-quality and acceptable Karish cheese with increased yield. Domiati cheese production was attempted earlier by an Egypt-based company, but the cheese obtained was inferior to that made from fresh milk. The recombined Domiati cheese had a firm texture and developed weak flavor even after the normal maturation period. Later attempts were made to improve the quality of recombined Domiati cheese, and direct addition of skim milk powder to buffalo or cow milk up to 35% total solids and coagulating the concentrated milk covered with brine resulted in acceptable taste and flavor after a month of storage. The FDA recommends the use of nonfat dry milk in processed cheese foods and processed cheese spreads. However, processed cheese made using cheese base produced from reconstituted skim milk powder results in markedly firmer cheese than the control. Skim milk powder has been reported for fortification of nontraditional white soft cheese in Egypt.

8. Conclusions

Utilization of whey proteins in cheese through either the adoption of techniques favoring WP retention in the cheese network or the direct addition of dairy-based ingredients or their combination is a challenging area in dairy sector. Some techniques have been implemented and emerged in industrial processes. In addition, ultrafiltration process can be used to restrain and recover whey proteins from drained whey that can later be added to the cheese milk. Utilizing whey protein into cheese preparation puts whey to good use. Whey protein-based edible films are a viable alternative packaging process for food and improvement of shelf life. Ghee residue is a good source of proteins, and about 100,000 tonnes of proteins can be recovered annually from GR only, and this can help in combating severe problem of protein-energy malnutrition. Potential uses of either crude or purified caseins include the production of plastics, adhesives, gels, composites, and films.

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References

[1] Fox PF, Guinee TP, Cogan TM, McSweeney PLH. Factors that affect cheese quality. In: Fundamentals of Cheese Science. New York: Springer; 2017. pp. 533-542

[2] Jelen P. Utilization and products. Whey processing. Encyclopedia of Dairy Sciences. 2011:731-738

[3] Yadav JSS, Yan S, Pilli S, Kumar L, Tyagi RD, Surampalli LY. Cheese whey: A potential resource to transform into bioprotein, functional/nutritional proteins and bioactive peptides. Biotechnology Advances. 2015;**33**:756-774

[4] Bugnicourt E, Schmid M, Nerney OM, Wild F. Wheylayer: The barrier coating of the future. Coating International. 2010;**43**(11):7-10

[5] Onwulata CHP. Whey processing, functionality and health benefits. In: IFT Press Series; Variation: IFT Press Series. Ames, Iowa, USA: Wiley Blackwell; 2008

[6] Ramos ÓL, Pereira JO, Silva SI, Fernandes JC, Franco MI, Lopes-da-Silva JA, et al. Evaluation of antimicrobial edible coatings from a whey protein isolate base to improve the shelf life of cheese. Journal of Dairy Science. 2012;**95**(11):6282-6292

[7] Ramos OL, Fernandes JC, Silva SI, et al. Edible films and coatings from whey proteins: A review on formulation, and on mechanical and bioactive properties. Critical Reviews in Food Science and Nutrition. 2012;**52**(6):533-552

[8] Hinrichs J. Incorporation of whey proteins in cheese. International Dairy Journal. 2001;**11**:495-503

[9] Mleko S, Foegeding EA. Physical properties of rennet casein gels and processed cheese analogs containing whey proteins. Milchwissenschaft. 2000;**55**:513-516

[10] Suzuki M, Asano Y, Fujita H, Inoue N, Abe T, Ochi H, et al. Effect of whey protein concentrate addition on the physical properties of low fat processed cheese. Journal of the Japanese Society for Food Science and Technology. 2012;**59**(3):122-126

[11] Ashour MM, Baky AA, El Neshawy AA, Salem OM. Improving the quality of Domiati cheese made from recombined milk. Food Chemistry. 1986;**20**(2):85-96

[12] Dhanraj P, Jana A, Modha H, Aparnathi KD. Influence of using a blend of rennet casein and whey protein concentrate as protein source on the quality of Mozzarella cheese analogue. Journal of Food Science and Technology. 2017;**54**(3):822. DOI: 10.1007/s13197-017-2528-5

[13] Kelly AL, Huppertz T, Sheehan JJ. Pre-treatment of cheese milk: Principles and developments. Dairy Science and Technology. 2008;**88**:549-572

[14] Lipnizki F. Cross-flow membrane applications in the food industry. In: Membrane Technology for Food Applications. Vol. 3. Weinheim: Wiley-VCH; 2010

[15] Pawar N, Gandhi K, Purohit A, Arora S, Singh RRB. Effect of added herb extracts on oxidative stability of ghee (butter oil) during accelerated oxidation condition. Journal of Food Science and Technology. 2012. DOI: 10.1007/s13197-012-0781-1

[16] Gandhi K, Arora S, Pawar N, Kumar N. Effect of vidarikand (extracts) on oxidative stability of ghee: A comparative study.

Research & Reviews: Journal of Dairy Science and Technology. 2013;**2**(1):1-11

[17] Dairy India. Milk movements, utilization and trade. 1985;**1981**(82): 20-24

[18] Santha IM, Narayanan KM. Composition of ghee-residue. Journal of Food Science and Technology. 1978:24-27

[19] Santha IM, Narayanan KM. Composition of ghee-residue lipids. Indian Journal of Dairy Science. 1978:365-369

[20] Tamine AY. Dairy Fats and related Products. Blackwell Publishing Ltd; 2009

[21] Verma BB, De S. Preparation of chocsi due burfi from ghee residue. Indian Journal of Dairy Science. 1978:370-374

[22] Galhotra KK, Wadhwa BK. Chemistry of ghee-residue, its significance and utilization—A review. Indian Journal of Dairy Science. 1993:142-146

[23] Pruthi TD, Narayanan KM, Bhalerao VR. Indian Journal of Dairy Science. 1971;**24**:185

[24] Vanderghem C, Bodson P, Danthine S, Paquot M, Deroanne C, Blecker C. Milk fat globule membrane and buttermilks: From composition to valorization. Biotechnology, Agronomy, Society and Environment. 2010;**14**:485-500

[25] Sodini I, Morin P, Olabi A, Jime'nez-flores R. Compositional and functional properties of buttermilk: A comparison between sweet, sour, and whey buttermilk. Journal of Dairy Science. 2006;**89**:525-536

[26] Dewettinck K, Rombaut R, Thienpont N, Le TT, Messens K, Van Camp J. Nutritional and technological aspects of milk fat globule membrane material. International Dairy Journal. 2008;**18**:436-457

[27] Rombaut R, Camp JV, Dewettinck K. Phospho- and sphingolipid distribution during processing of milk, butter and whey. International Journal of Food Science and Technology. 2006;**41**: 435-443

[28] Tamime AY, Robinson RK. Yoghurt: Science and Technology. Cambridge, UK: Woodhead Publishing Ltd.; 1999

[29] Sayed MME, Askar AA, Hamzawi LF, Fatma FA, Mohamed AG, El Sayed SM, et al. Utilization of buttermilk concentrate in the manufacture of functional processed cheese spread. Journal of American Science. 2010;**6**(9)

[30] Govindasamy-Lucey S, Lin T, Jaeggi JJ, Johnson ME, Lucey JA. Influence of condensed sweet cream buttermilk on the manufacture, yield, and functionality of pizza cheese. Journal of Dairy Science. 2006;**89**:454-467

[31] Kumari J, Kumar S, Gupta VK, Kumar B. The influence of mixing sweet cream buttermilk to buffalo milk on quality of Chhana production. Milchwissenschaft. 2012;**67**:57-60

[32] Bahrami M, Ahmadi D, Beigmohammadi F, Hosseini F. Mixing sweet cream buttermilk with whole milk to produce cream cheese. Irish Journal of Agricultural and Food Research. 2015;**54**:73-78

[33] Suneeta P, Bhatt JD, Prajapati JP. Evaluation of selected emulsifiers and buttermilk in the manufacture of reduced-fat Paneer. Basic Research Journal of Food Science and Technology. 2014;**1**(4):1-14

Section 3

Supply Chains and Consumers

Chapter 4

A Synthesis of Risks in Dairy Value Chains in Southern Africa: Cases of South Africa and Zimbabwe

Chari Felix and Ngcamu Bethuel Sibongiseni

Abstract

An increase in frequency and intensity of slow- and fast-onset disasters in Southern Africa has crippled milk producers' value chain with catastrophic effects to consumers. Milk production is vulnerable to disruptions from natural disasters, poor transport and infrastructure. The chapter considers the cases of South Africa and Zimbabwe, two countries that have organized dairy production. Against this bleak backdrop, this chapter explores the contribution of the milk industry to the economy and the benefits to consumers of milk and dairy products. The chapter also identifies the key players in the dairy supply chain in Southern Africa. It explores different types of disaster risks prevalent in Southern Africa and how they affect the production of raw and processed milk along dairy supply chains. It further interrogates risk management strategies employed by the key players to mitigate these risks to make dairy supply chains sustainable. This chapter reviewed literature and analyzed governments, non-governmental organizations, and industries' documents with the aim to present value chain resilience strategies. This chapter also presents an insight into the policymakers and milk industries on the risk reduction strategies that are employed to mitigate the effects of risks on the milk and dairy products' value chain.

Keywords: dairy industry, drought, milk production, risk reduction strategies, value chain

1. Introduction

The Southern African Development Community (SADC) has experienced the growing demand for dairy products, increased the milk returns, employee productivity, quality milk yields, and demand, as well as the application of world-class technology. Mlambo and Zitsanza [1] contemplate this growing demand which has led to the dairy industry's contribution to the economic development of both South Africa and Zimbabwe. Furthermore, the price fluctuations in the SADC region have led to an increase in the milk demand. The milk production, favorable trade, and job creation can be utilized as criterions to determine the economic benefits of the dairy industry.

The agricultural sector contributes to the gross domestic product (GDP) of the emerging and developing countries including South Africa and Zimbabwe. Hence, the dairy demand is expected to grow by 2.3% a year over the next decade.

Figure 1.
Effects on the demands of the dairy products. Source: authors.

The primary drivers of growth in demand remain population growth and growth in the per capita consumption of dairy products [2]. There is a plethora of benefits in improving the levels of milk production and profitability of dairy farmers. These include the following (**Figure 1**):

- A growing demand for dairy products in developing countries and SADC countries are no exception.
- An increase in milk returns.
- An increase in labor productivity.
- An increase in milk yields.
- The creation of job opportunities.
- Improved demand for quality of milk and its price.
- Improved supply of milk yields by the utilization of production in technology.
- Acceleration of women empowerment.
- Development of farmers' cooperatives.

In Zimbabwe, the agricultural sector provides employment and livelihood to 70% of the population, contributing between 40 and 60% of exports and 15–25% of gross domestic product (GDP) [3]. The dairy sector is equally critical for the success of rural communities as it reduces poverty and ensure food and nutrition security. At the height of production in 1990, milk production reached an all-time annual high of 262 million liters [4]. However, the estimated demand for milk and milk products of 180 million liters in Zimbabwe presents a supply gap of 129 million liters, implying that there is an opportunity for import substitution through improved competitiveness and increased production, especially from local smallholder dairy farmers [4].

On the contrary, the World Wildlife Fund South Africa (WWF [5]) suggests that the South African dairy products import percentage has superseded the export percentage since 2010, although the South African milk production has been changing relatively. *Agriculture Statistics* [6] posits that over the last 20 years, the milk production has remained constantly due to the substantial decrease of the dairy of the national herd. The sudden change in production occurred even though the number of farmers has declined since 1993 with the dairy sectors being detrimentally affected [7], whereas international dairy product prices dropped by 61% from February 2014 to May 2016. The decrease in prices was caused by higher production, fueled by higher producer prices, and a decrease in demand, especially from China [2]. Furthermore, the milk consumption in South Africa has declined, and South African farmers are unable to compete against farmers from the first world countries who receive state funding from their countries and export their products to South Africa. Hence, this slow-onset disaster (drought) had a multiplicity of repercussions including the severe depletion of the natural grazing with livestock slaughter, reduction of summer crop plantations, extreme temperatures in summer months, and grain deficits with an increase in importations. Furthermore, the inability of the agricultural sector to attract clients with purchasing power, a depreciating currency, and an increase in food prices were the effects of drought in southern Africa. It is imperative to investigate the risk issues in the dairy value chain due to the importance of the dairy industry in regional economic development, contribution to the GDP, and poverty alleviation.

2. Milk production value chain

The scarcity of farmland and water has limited the growth of the dairy industry. The key players in the value chain are input suppliers, dairy farmers and milk processors, middlemen, government, financial institutions, nongovernmental organizations, buyers in the markets, and value chain supporters. Both large-scale and many smallholder dairy farmers in the country need several inputs from input suppliers to raise the cows and produce raw milk. South African and Zimbabwean milk production is dominated by large-scale farmers who own fairly large farms with high producing pure exotic cows. The other players in the dairy value chain in Zimbabwe are middlemen (wholesalers and retailers) who buy milk produce from farmers and processors in bulk in order to retail to the consumers. The sale of milk and milk products is through supermarkets and shops around the country. The processing companies also sell milk products directly to final consumers through their salesmen who patrol streets in towns and residential areas with refrigerated push and bicycle carts. The other key players are the consumers of the milk products themselves. Without the consumers in the value chain, there is no business; hence, milk products' consumers are important in the milk value chain. Dairy value chain supporters provide support to the main actors to guarantee that dairy products get to the final consumer. The supporters in the dairy value chain in Zimbabwe include:

dairy services, the Department of Veterinary Services, Livestock Research Institute, extension services, farmers' unions, and nongovernmental organizations.

There are a multiplicity and diverse actors in the dairy supply value chain who perform various pivotal roles that service dairy industries including educators from agricultural schools, universities and technical colleges, farmers and stock people, farm advisors, local agribusiness, policymakers, and research scientists. There are also pivotal key stakeholders in the dairy value chain in South Africa which include the Department of Agriculture, Forestry and Fisheries, National Disaster Management Centres, Industrial Development Corporation, Land Bank, Banking Association of South Africa, South African National Consumer Union, and National Chamber of Milling. The stakeholders aim to improve the productive performance of the training and development programs and training on the foundations of dairy production technology. Midgley [8] mentions that consumers, dairy processors, informal traders, retailers, bulk milk collectors, transport operators, importers and exporters, and large commercial and medium and small dairy producers can be considered as the dairy supply value chain. The author argues that the dairy industry has noticed the number of producers declining with the cattle sizes increasing and the milk production efficiencies improving.

3. Drought effects in the dairy industry

The SADC region has been prone to drought, which is associated with the climatic phenomena called EL NINO. This phenomenon occurred when sea temperatures surpassed the Western coast of South America affecting global weather patterns. The effects of EL NINO in South Africa has resulted in seven out of nine provinces being declared disaster zones which had catastrophic effects on the dairy supply including the milk. The severe impact of drought in the SADC region with South Africa as no exception has drastically paralyzed the milk supply value chain. This became conspicuous as most dairy farmers were unable to produce and supply sufficient milk due to the impact of drought which has increased the cost of milk drastically. Consequently, this led to the majority of dairy farmers in South Africa to experience a reduction in the milk production, which led to an increase in prices by retailers which had an adverse effect on consumers. The local supply situation remains uncertain as the final effect of the 2016 and 2017 drought remains to be seen. Lower grain prices will probably have a beneficial effect on production but the scarcity of roughage, higher beef prices, and the weaker condition of herds after the drought impacted negatively on production. Milk production growth remained slow during the rest of 2017 [2]. There are a number of factors that have necessitated some dairy processors to pay commercial farmers an exorbitant amount of money per liter per average for milk to ensure a consistent supply which includes, *inter alia*:

- The effects of drought leading to poor pasture conditions.
- Increase in grain prices.
- Importation of dairy products (milk) from other countries was very expensive as the Rand was very weak despite lower international prices.
- The volatile exchange rate made imports expensive.
- Increase in electricity tariffs increased input costs for farmers and milk processors.

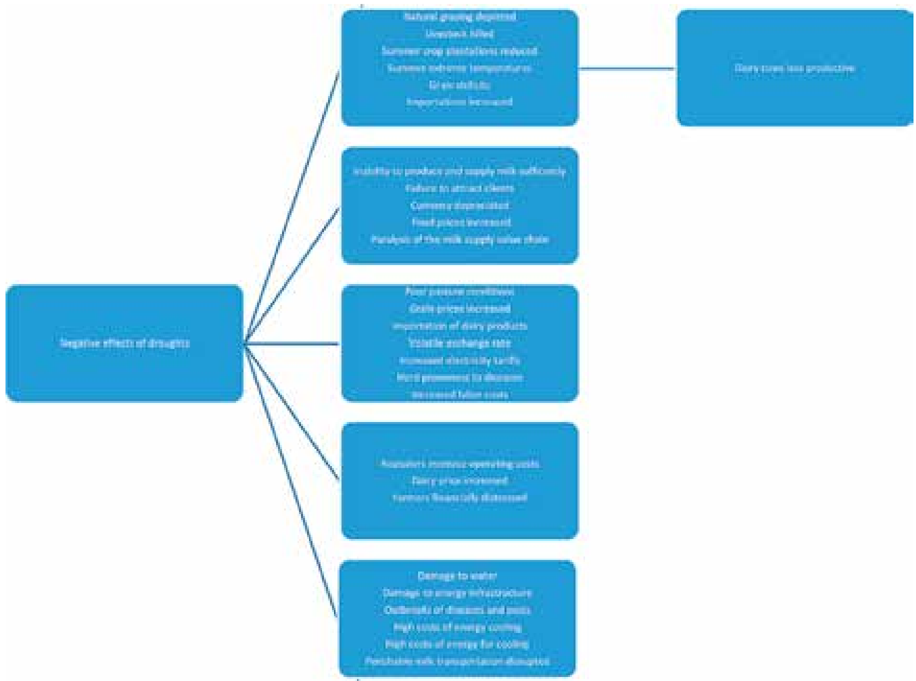

Figure 2.
Adverse effects of droughts in the dairy supply. Source: authors.

The above factors have influenced retailers to increase operating costs for the entire milk value chain, which necessitated retailers to increase the dairy milk and other dairy products which consumers purchase at a hefty price. Lakew [9] opines that the dairy farmer's profitability on their products are negatively affected; a reduction in the production of milk and unfavorable balance of trade can be originated on the decline in the production of milk (**Figure 2**).

Transporters collect and transport bulk raw milk from farms to processing plants, usually situated in towns. In Zimbabwe, the transport system is dominated by the National Dairy Co-operative (NDC), an organized farmers' co-operative transport organization. The transporters use refrigerated bulk tanks to ensure that the quality of milk is maintained. The major processing companies are Dairibord Zimbabwe Private Limited (DZPL), Dendairy (Pvt) company, and Nestle Zimbabwe, which add value to raw milk by being processed into various milk products such as yogurt, cheese, pasteurized milk, ice cream, and butter.

4. Risks in dairy value chains

The complex dairy value chain comprises dairy farmers, transporters, processors, wholesalers, retailers, and consumers who use milk products created in the value chain [10]. The dairy supply chain is vulnerable to disruptions from numerous risks as it involves many stakeholders. Risks may arise from any component within its supply chain. According to Gertenbach [11], environmental factors which include temperature, rainfall (quantity and distribution), sun hours, and soil types contribute significantly to livestock production. Climate change has negatively affected the SADC region's dairy farmers and industry in particular. For instance, the increased temperatures have decreased the dry matter intake for animals, reproductive performance declined, and the overall productivity declined. Heat stress impairs milk production, reproductive performance, metabolic and health status, and immune response. The dairy cows are less productive in the event of increased temperature levels. Hence, cows that are experiencing extreme heat are identified by the signs of the reduced feed intake, which directly contributes to the decreased milk yield. The extreme climatic variations which are prevalent in the SADC region have both direct and indirect impacts on the dairy cattle where the following have been identified:

- Fodder and pasture yields decreased,
- Increased susceptibility to diseases,
- Shortage and increased feed costs.
- Infrastructural destruction, and
- Cost increase due to overutilization of energy.

The main risks associated with Zimbabwe dairy include financial, technology, political unrest, policy barrier, and natural disasters.

4.1 Financial risks

To purchase the required infrastructure in the dairy industry requires large sums of money [12]. The high perishability of milk requires dairy farmers to make substantial capital investments right from production up to sale. The procedure to secure finance in Zimbabwe is burdensome and highly bureaucratic and complex [12]. Credit providers have become more risk-averse and are equally reluctant to offer loans to farmers producing on land that lacks collateral value. Women entrepreneurs are adversely affected where banks demand collateral security in the form of property in urban areas for them to access business loans. Fewer women than men own fixed assets [13]. High lending rates of up to 14% [14] make the cost of capital expensive. Available financing is more suitable for short-run farming projects, while there is limited availability of medium to long-term finance for the broader agricultural sector. Resultantly, farmers are unwilling to make long-term investments in dairy farming leaving Zimbabwe food insecure [15].

4.2 Input risks

The most important dairy component is the livestock itself—the heifers. Building the dairy herd takes long gestation periods of up to 9 months. The long gestation makes it difficult to grow the herd much faster to boost milk output. In like manner, dairy farmers incur high costs to breed or purchase heifers which become a production constraint [12]. An equally important input is electricity provided by a state-owned monopoly, the Zimbabwe Electricity Supply Authority (ZESA). The frequent disruptions in power supplies have seen a decrease in capacity utilization in the agricultural sector which, in turn, affects capacity utilization simultaneously fuelling input costs in the dairy industry as the dairy processors have to consider other sources of power like generators to prevent disruptions in their production lines [16]. The high-input costs push the price of the final milk products up.

Furthermore, the Zimbabwe dairy industry has very high labor costs negatively affecting viability. An increase in labor costs reduces returns, and income earned may not be adequate to cover costs [17]. Zimbabweans are among the heavily taxed in the world. Currently, above paying taxes to the Zimbabwe Revenue Authority, dairy producers pay levies to the Dairy Services Department, Environmental Management Authority, Agriculture Marketing Authority, Local Authorities, and Zimbabwe National Water Authority, among others [18].

4.3 Political risks

The poor performance in the agricultural sector is also as a result of poor government policies. During the period from 1998 to 2000, Zimbabwe experienced negative economic growth. There was political instability in Zimbabwe following the fast track land reform program. The political instability negatively affected milk production as large-scale commercial dairy farmers were among those who lost their farms land invaders [19]. Following the implementation of the fast track land reform, cattle population declined. It is estimated that the dairy herd was reduced by 50% from what it was before the land reform program in year 2000. Land tenure security is threatened by lack of title deeds, and therefore, dairy farmers are not prepared to make long-term investments, negatively affecting milk quantity and quality [20]. Political commitment to creating an enabling environment for investment growth in Zimbabwe is questionable and uninspiring [21].

The other challenge that local farmers face is their limited capacity to influence policy outcomes. Intervention by NGOs is heavily restricted by the restrictive political environment. Governance concerns continue to block any progressive success made toward foreign interventions in the form of assistance from emergency interventions to long-term development support.

4.4 Competition risks

The high costs of breeding dairy cattle translate to very uncompetitive raw milk which costs US $0.62 per liter compared to neighboring South Africa and Kenya, which costs US $0.40 and US $0.30, respectively [22]. There is fierce competition emanating from the influx of foreign milk and milk products from plants in Europe and South America, which is choking the dairy industry to date [23]. Most dairy products from South Africa are threatening the agricultural sector, thereby prompting dairy farmers and processors to come up with initiatives that promote the buying and consumption of locally produced dairy products to mitigate the unfair competition from foreign dairy products [24, 25].

4.5 Natural disaster risks

The disastrous drought which affected the SADC region between the period of 2015 and 2017 has negatively affected the already ailing agricultural sector (commercial, small holding, and subsistence) which left farmers financially distressed. The intensity and magnitude of drought which struck South African farmers including dairy farmers were beyond their world-class disaster contingency plans. Even though South African farmers are recognized as the best in the world in terms of their planning and production and risk assessment and planning, they did not cope with the disaster. The extreme risk to the dairy production and its value chain is associated with the climatic variations with mostly the variable weather conditions more especially droughts. The recent slow-onset disaster (drought) directly affects both rain-fed and irrigated pastures, as well as prices of purchased feeds. The climatic risks also encapsulate erratic rainfall patterns, heavy rainfall and floods, and heat waves. Extreme weather conditions have negative repercussions which include damage to water and energy infrastructure; outbreaks of pests and diseases; high costs of energy for cooling under hot conditions; and disruption of transport of perishable milk due to road and bridge destruction.

While all countries suffer from disasters, low-income countries are more susceptible to the impact of disaster risks. The natural and manmade disaster risks have severely disrupted dairy production, thereby leading to increased prices of dairy produce, decreased sales, and created perpetual vulnerability. Unexpected climate change affecting Zimbabwe and other southern African countries are exposing dairy farmers to both production and marketing risks. They tend to affect many farms and dairy processing firms. Secondary data available on climatology such as rainfall pattern erraticism and extreme weather events in Zimbabwe show that the country is already experiencing the effects of climate change [26].

The unbearably high temperatures extended Zimbabwe's dry regions that are less productive, thereby shrinking the main farming regions. These human-induced climate changes are caused by the greenhouse effect [27] and mostly affect African countries like Zimbabwe resulting in food insecurity. The challenges posed by unforeseen climate changes are depleting the most essential natural resource, water. It is increasingly becoming difficult to sustain viable agriculture given such harsh, unpredictable weather conditions for many agro-based economies like Zimbabwe. Rain-fed agriculture is becoming less reliable to maximize agricultural productivity.

Zimbabwe, being an agro-based economy, faces severe threats from these climatic changes. Dairy farming, in particular, thrives well in regions which record high rainfall. Zimbabwe, in particular, is at risk and is vulnerable to these new climatic conditions because it heavily relies on rain for its agricultural activities [28]. These erratic rainfall patterns and dry spells are impacting negatively on the productivity of dairy farms. The low rainfall experienced in Zimbabwe country makes dairy cows breeding more difficult by the day as there are changes in feed resources [29].

Over a million cattle starved to death as a result of the 1991/1992 drought [30, 31]. The impact of the drought was felt by individual farmers, as well as all the industries dependent on agricultural raw materials such as milk and beef processing [31]. The 2015/2016 drought threatened food security in Zimbabwe as thousands of cattle starved to death due the drought [32]. Grazing conditions remained poor in most of the southern half of the region [32]. The foot-and-mouth disease (FMD) of year 2015 also contributed to the calamity as it resulted in a decline in the national herd [33].

4.6 Technology risks

Poor technology in Zimbabwe, among other factors, has adversely affected capacity utilization in the milk processing industry [34]. Dairy farmers face technological risks as they have problems cooling milk in areas without electricity, adversely affecting the quality of milk. Consequently, some farmers use manual milking which is quite difficult for large herds. Low agricultural output is, therefore, attributed to the low capital endowment (Zimbabwe Vulnerability Assessment Committee [35]).

5. Risk management strategies employed by stakeholders

Various strategies which can be harnessed in order to increase domestic milk production and yield a positive contribution to the economy include, *inter alia:*

- Prioritizing increasing the number of dairy farmers without emphasizing changing the average milk production per cow or farm.

- Emphasizing the increasing yields per cow milk rather than expanding the population of dairy farmers.

- Increasing the total number of the milking herd (cows) without changing dairy farms.
- Increasing the number of dairy farms, the size of the milking cows, and per cow production combined.
- Reforming small holding dairy farms to larger farms and "mega farms."
- To eliminate wastage at the production plant (farm) and by the consumer.
- To avoid the high mortality rates of young stock.
- The development of a national breeding center.
- The importation of breeding heifers.
- To have a skilled labor force.

There is no straight solution to manage risks. Each value chain possesses its uniqueness; so, the criterion for management differs from others. Various risk mitigation strategies to mitigate the risks associated with the dairy value chain are explored in this section. The dairy farmers have utilized various mitigation strategies. These strategies include the use of smaller dairy breeds like Jersey, growing fodder crops, and the utilization of crop residences.

Furthermore, the low-cost to high-cost adaption strategies have been utilized to counter heat stress on dairy cattle productivity and reproductive performance. The low-cost measures employed by farmers include reducing overcrowding, maximizing shade, improving ventilation, and high-cost measures included the designing and installation of thermos air conditioning. Both adaptation and mitigation strategies were utilized by dairy farmers to ensure that production and productivity inputs are at an optimal level. Sprinkler fans, changing the feeding periods to coincide with the cooler times of the day and reducing the exertion required by animals to gain access to food, minerals, and water are the mitigation strategies that were being employed by farmers.

To fully implement the above strategies dairy farmers relied on collaboration, legislation and policy, education and training, insurance, technology, and international assistance [15]:

5.1 Collaboration

A plethora of commentators [36–38] opine that a key strategy to effectively mitigate risk on dairy supply is through collaboration among key stakeholders. Such key stakeholders from diverse sectors and disciplines including leaders of government ministries, NGOs, and private sector organizations play a pivotal role in risk reduction. The collaboration and partnership of stakeholders yields positive results as partner organizations share skills, technical knowledge, information and resources, experiences, and best practices resulting in saving money due to elimination of duplications and wastage. Collaboration is also evident in Zimbabwe's dairy sector. The Zimbabwe farming community has formed collaborations with NGOs to try and mitigate exposure to risk. There are many NGOs providing assistance in the agrarian sector in Zimbabwe of which Technoserve, Land O'Lakes, European Union, United States Agency for International Development (USAID), and Zimbabwe Agricultural Competitive Program (ZimACP) are active in providing support and assistance to the dairy farming sector [21].

NGOs such as Land O'Lakes partner National Association of Dairy Farmers (NADF) train community livestock workers in dairy management [39]. Likewise, milk processing companies, Dairibord Zimbabwe Holdings, Nestle Zimbabwe, and Dendairy develop small, medium, and large-scale farmers across the country through heifer programs to boost milk production [40]. The livestock was distributed to farmers in an effort to ensure continuity of supply across the supply chains. According to the Dairibord Holdings Annual [40], this milk supply intervention has realized benefits as it has contributed 8% to the milk supplies for Dairibord Zimbabwe.

5.2 Legislation

Disaster legislation is one of the instruments that can highlight the efforts and commitment a country has in disaster reduction and management practices. This section highlights the legal and institutional framework that deals with risk reduction and management in Zimbabwe. The Civil Protection Department is tasked with the mandate of preparing for and providing for prevention where possible, as well as mitigating the effects of disaster whenever it occurs, through the Civil Protection Act of 2001 [41]. This was a reflection of the government's commitment to disaster management [42]. The Civil Protection Act of 2001 resulted in the setting up of a Civil Protection Department under the flagship of the Ministry of Local Government, Rural and Urban Development [43]. Besides the Zimbabwe Civil Protection Unit efforts, there has been an increased focus on disaster risk reduction (DRR) by other sectors of government. The Zimbabwean Civil Protection Act is complimented by other acts: Environmental Management Act (20:27), the Rural District Councils Act (29:12), the Urban Councils Act (29:14), the Water Act No. 31 of 1998, the Defence Act (11:02), the Police Act (11:10), and the Public Health Act (15:09) [44].

5.3 International assistance

Zimbabwe is among the top 40 recipients of disaster risk reduction (DRR) financing from humanitarian organizations. However, there is still a concentration of DRR financing by these humanitarian organizations within the top four recipients (Pakistan, India, Indonesia, and Bangladesh) [45]. The farming community has formed collaborations with international NGOs to try to mitigate exposure to risk. There are many NGOs providing assistance in the agrarian sector in Zimbabwe of which Technoserve, Land O'Lakes, European Union, USAID, and Zimbabwe Agricultural Competitive Program (ZimACP) are active in providing support and assistance to the dairy farming sector [21]. The activities of these organizations are coordinated by the Food and Agriculture Organization.

5.4 Policy

In a plight to increase agricultural activity and curb the risks posed by natural hazards in Zimbabwe, various stakeholders have formulated the Comprehensive Agricultural Policy Framework (2012–2032) [46]. Due to changes in the socio-economic environment, such as the land reform program, there has been a need to review the national agricultural policy. The policy is aimed at, among other issues, increasing production and productivity of livestock and improved animal health and welfare in the country [46]. The Comprehensive Agricultural Policy Framework also recommended agricultural subsidies so that local farmers will be able to compete with imports. Despite these noble efforts, a gap still exists concerning agricultural policy formulation and implementation which will guide any programs directed toward mitigation of natural hazards and meteorological disasters like drought. Zimbabwe has to date made many attempts to create a comprehensive agricultural policy, which have remained in draft form to date [21].

5.5 Education and training

Education and training strengthen all aspects of risk management at all the stages in the risk management cycle. Risk management (RM) education can be introduced in school curricula. Zimbabwe has successfully integrated DRR and emergency preparedness into its education system. Education would be a handy strategy with most dairy farmer's literate (96%) and are able to interact with providers of farmer training courses [47]. Similarly, conferences compliment formal education and workshop training [48].

5.6 Insurance

Zimbabwe has a total of 25 registered insurance companies and 15 insurers, representing about 60%, which currently provide agricultural insurance [49]. However, there is a low penetration of agricultural insurance products in the country. Furthermore, insurers do not provide specialized agricultural insurance packages. Insurance enables the farmers to transfer risks to insurance companies [50]. Insurance reduces individual loss exposure, thus spreading risks by collecting premiums from many individuals and paying for damage caused by natural disasters that are very large for individual households and companies. Agricultural insurance policies cover against a many risks including drought, floods, heat waves, and other natural disasters. One such insurance by Zimnat Lion Insurance, Zimnat Livestock Insurance, insures farmers against fire, theft, lightning, explosion, and death of livestock [51].

5.7 Technology

Most dairy farms in the developed world make use of emerging technologies to improve efficiency and profitability in dairy enterprises. In particular, automation technology is used to improve profitability, milk quality, reduce costs of production, and improved animal welfare. These new automated technologies have incorporated computers and cellphones application to manage milk production and animal health. Various technologies recommended to dairy farmers in Zimbabwe were first tested on demonstration plots before they were adopted across the country. However, adoption of these technologies was a hurdle to poor farmers because of resource unavailability [52].

5.7.1 Emerging technologies and benefits in the dairy industry

The dawn of the agricultural revolution which is engrained on technology has increased efficiency and profitability in the South African and Zimbabwean dairy industry. The introduction of technology has boosted milk yields, enhanced milk quality, and reduced the costs associated with producing white stuff. **Table 1** depicts emerging technologies and benefits in the dairy industry.

The abovementioned technologies assist the dairy industry production as there is a scarcity of committed labor in both the developing and developed countries. Furthermore, such new technologies save time and reduce labor expenses, thus increasing efficiency, productivity, and profits.

Technology	Benefits
Cow collars	• Track and collect data on the health, habits, and happiness of the herd. • Data can be accessed anywhere by using modern devices including laptop or smartphones. • Share abnormal information with a vet. • Detect illness and respond early. • Detect when the cow is in heat. • Boost chances of healthy pregnancies which enhance milk production.
Drone technology	• Monitor the location of the herd. • Monitor the entire farm and identify early risks including: ○ Intruders. ○ Stock thieves. ○ Illegal invaders. ○ Identify perimeters that need repair. ○ Identify areas of dry land that require irrigation. ○ Monitor the entire farming business.
Facial recognition technology	• Using details such as: ○ Pelt patterning. ○ Distance between the ages and length of face. • Detect each cow in a dairy farmer's herd. • Send alerts when a cow behaves erratically: ○ Walking irregularly or missing feeds. ○ Track the link between each cow's food intake and their milk production.
Robotic milking technology	• Enhanced milk yields.

Table 1.
Emerging technologies and benefits in the dairy industry.

6. Conclusion

This chapter espoused the high level of preparedness and resilience by dairy farmers during and in the aftermath of droughts to selected countries. It is observed in this chapter that while drought effects have paralyzed the dairy industry, the demand of dairy products has remained constant. The increase of the demand of the dairy industry has improved the quality of life of people as it provided formal and seasonal employment. Moreover, it also increased competition among the dairy farmers coupled with profits gained. Consumers also benefited as they have purchased quality dairy products which were influenced by the competition among dairy industries. This chapter has depicted the adverse effects of drought which have affected the dairy supply value chain from the grazing fields, herd health and productivity, infrastructure, economy, and resource availability. Various technological inventions and applications have been seen as beneficial to dairy farmers which has increased the health and productivity of cows, monitoring of the entire business and detection strategies which have increased cow milk yields. The technological, financial, political, and natural disasters and input risks have been the dominant risks in the dairy supply chain and have had catastrophic effects on consumers. Various risk mitigation strategies have been implemented to mitigate the risks associated with the dairy supply chain that includes collaboration, legislation, policy, education and training, technology insurance, and international assistance. However, most strategies failed because of unavailability of resources to fully implement them.

A major limitation in this study is methodological in nature as this chapter only employed a document analysis. This research method makes it difficult to test the reliability and validity of the findings as inferences cannot be used to other countries. It is advisable for future researchers to employ various methodologies and approaches in both countries where reliability and validity testing will be conducted.

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References

[1] Mlambo K, Zitsanza N. Economies of scale, capacity utilization and productivity measurement in Zimbabwean commercial agriculture. African Development Bank Reviews. 2001;**9**(2):15-32. DOI: 10.1111/j.1467-8268.1997.tb00153.x. Available from: http://www.afdb.org/knowledge/reviews/reviews_vol9_n2.htm

[2] Coetzee K. Global dairy crisis is over. The Dairy Mail. 2017

[3] Food and Agriculture Organisation (FAO). Crop and Food Supply Assessment Mission to Zimbabwe: Special Report. 2003. Available from: ftp://ftp.fao.org/docrep/fao/005/y9730e/y9730e00.pdf

[4] Stichting Nederlandse Vrijwilligers. Evaluation of Small Holder Dairy Programmes in Zimbabwe. SNV Report; 2012

[5] WWF SA. Agriculture: Facts and Trends. South Africa. 2015

[6] Agriculture Statistics. Directorate: Agricultural Statistics of the National Department of Agriculture, Pretoria; 2008

[7] Census of Commercial Agriculture. Agricultural Statistics South Africa. Statistics South Africa; 2008. Available from: http://www.statssa.gov.za

[8] Midgley SJE. Commodity Value Chain Analysis for Dairy. South Africa: WWF-SA; 2016

[9] Lakew 2017. 2015/2016 Agriculture season-January-February Update; 19 February 2016. Issue no. 6. Available from: www.sadc.int/fanr

[10] Curtis M. Milking the poor: How EU subsidies hurt dairy producers in Bangladesh. Dhaka. 2011

[11] Gertenbach W. Dairy farming in South Africa: Where to now? Institute for Animal Production, Western Cape Department of Agriculture; 2006. Available from: www.fao.org

[12] Hahlani CD, Garwi J. Operational Challenges to Small Dairy Farming: The Case of Maryfield Dairy Settlement Scheme in Chipinge District of Zimbabwe. 2014;**19**:87-94. Available from: www.iosrjournals.org

[13] Zimbabwe National Chamber Of Commerce (ZNCC). Women Agribusiness Entrepreneurs in Zimbabwe: Evaluating Access to Capital and Markets. Nathan Associates. 2016. Reviewed by the United States Agency for International Development. Retrieved from: http://www.zncc.co.zw/docs/Zimbabwe-Women-EntrepreneursFinal.pdf [Accessed: 10 October 2016]

[14] Commercial Farmers Union. Zimbabwean agriculture within an African global context. In: 71st Annual Congress Report, 28 October, 2014. 2014. Retrieved from: http://www.cfuzim.org/~cfuzimb/images/brochure2014.pdf [Accessed: 12 December 2015]

[15] Chari F, Ngcamu BS. An assessment of the impact of disaster risks on dairy supply chain performance in Zimbabwe. Cogent Engineering. 2017;**4**:1409389

[16] Nyakazeya P. Power cuts costing Zimbabwe millions. 2016. Retrieved from: http://www.financialgazette.co.zw/power-cuts-costing-zim-millions/ [Accessed: 06 April 2016]

[17] Zvinorova PI, Halimani TE, Mano RT, Ngongoni NT. Viability of smallholder dairying in Wedza, Zimbabwe. Tropical Animal Health Production. 2013;**45**:1007. DOI: 10.1007/s11250-012-0325-8

[18] Mutono S. Milk production declines. The Patriot. 2014

[19] Mzumara M. An overview of Zimbabwe's macroeconomic environment. International Journal of Economics and Research. 2012;**v3i1**: 33-69. ISSN: 2229-6158. Available from: online@www.ijeronline.com

[20] Marecha TC. A case study of the zimbabwe dairy industry. SADC Stakeholders Sanitary and Phytosanity Awareness Workshop (Presentation); Pretoria; 12-13 Spetember, 2013 [Accessed: 18 January 2016]

[21] Anseeuw W, Kapuya T, Saruchera D. Zimbabwe's agricultural reconstruction: Present state, on-going projects and prospects for reinvestment. Development Planning Division, Development Bank of Southern Africa. Working Paper Series No: 32; 2012

[22] Kawambwa P, Hendriksen G, Zandonda E, Wanga L. Business Viability Assessment Study of Small Holder Dairy Farming in Zambia. Wageningen: Alterra; 2014

[23] Gadzikwa EC. The future of the manufacturing sector in Zimbabwe. Institute of Chartered Accountants of Zimbabwe Congress, 18-20 July 2013, Victoria Falls. Available from: https://www.icaz.org.zw/iMISDocs/manufacture.pdf. [Accessed: 21 May 2017]

[24] Mataranyika M. SA Imports Pose Threat. News 24 (Online). 2015. Available from: http://allafrica.com [Accessed: 05 February 2016]

[25] Mpofu B. Dairy Sector Pushes for Protectionism. News Day (Online). 2013. Available from: http://www.newsday.co.zw [Accessed: 16 January 2016]

[26] Brown D, Chanakira R, Chatiza K, Dhliwayo M, Dodman D, Masiiwa M, et al. Climate Change Impacts, Vulnerability and Adaptation in Zimbabwe. Working Paper No. 3; 2012

[27] Manyeruke M, Hamauswa S, Mhandara L. The effects of climate change and variability on food security in Zimbabwe: A socio-economic and political analysis. International Journal of Humanities and Social Science. 2013;**3**(6/special issue) p 270-286

[28] Chagutah T. Towards improved public awareness for climate related disaster risk reduction in South Africa: A participatory development communication perspective. JÀMBÁ. Journal of Disaster Risk Studies. 2009;**1**:2

[29] Masama E. Research note: Impact of climate change on livestock production in Zimbabwe. International Open and Distance Learning Journal. 2013;**2**(1):47-53. Available from: http://www.iodlj.zou.ac.zw/ejournal/index.php/journal/article/viewFile/74/77

[30] Gumbo, D. Zimbabwe: Country Case Study on Domestic Policy Frameworks for Adaptation in the Water Sector: OECH Global Forum on Sustainable Development. 2006. Retrieved from: http://www.oecd.org/environment/cc/36318866.pdf [Accessed: 26 July 2015]

[31] Maphosa B. Lessons from the 1992 Drought in Zimbabwe: The Quest for Alternative Food Policies. Nordic Journal of African Studies. 1994;**3**(1):53-58

[32] SADC Agromet. Food Security Early Warning Systems Update Agromet 2015/2016, Agriculture Season-January-February Update; 19 February 2016. 2016;**6**. Available from: www.sadc.int/fanr

[33] Zimbabwe Vulnerability Assessment Committee (ZimVAC). 2016 Rural Livelihoods Assessment. Harare: Zimbabwe Vulnerability

Assessment Committee (ZimVAC); 2016. Available from: http://reliefweb.int/sites/reliefweb.int/files/resources/zimvac_2016_rural_livelihoods_assessment.pdf

[34] Nyamwanza T, Mavhiki S, Nyamwanza L, Chagwesha M. Capacity utilisation strategies in the milk processing industry in Zimbabwe. The Journal of Management and Marketing Research. 2015;**19**:1-9

[35] Zimbabwe Vulnerability Assessment Committee (ZimVAC). Security Assessment. Harare; 2009

[36] Chen J, Sohal AS, Prajogo DI. Supply chain operational risk mitigation: A collaborative approach. International Journal of Production Research. 2013;**51**(7):2186-2199

[37] Guzman M. Total disaster risk management approach: Towards effective policy in disaster risk reduction and response. In: Regional Workshop on Total Disaster Risk Management 7-9 August; Philippines; 2002

[38] Murigi JM. Strategies of minimizing the effects of supply chain disruption caused by natural disasters in Kenya: A case study of Brookside dairy limited. Prime Journal of Business Administration and Management. 2013;**3**(4):971-978

[39] Land O'Lakes. Zimbabwe: Restoring Confidence in Milk Collection. Land O'Lakes: International Development; 2014

[40] Dairibord Holdings Limited. Annual Report 2015. 2015

[41] Government of Zimbabwe. Civil Protection Act. Harare: Government Printers; 2001

[42] Betera L. Overview of Disaster Risk Management and Vulnerability. Zimbabwe: Civil Protection Unit; 2011

[43] Bongo P, Chipangura P, Sithole M, Moyo F. A rights-based analysis of disaster risk reduction framework in Zimbabwe and its implications for policy and practice, Jamba. Journal of Disaster Risk Studies. 2013;**5**(2):2-11

[44] Shamano N. An investigation into the disaster risk reduction (DRR) efforts in Gutu District (Zimbabwe): A focus on drought early warning systems. In: Partial Fulfilment of the Requirements f or the Degree, Masters in Disaster Management in the Disaster Management Training and Education Center for Africa. University of Free State, Free State; 2010

[45] Kellett J, Spark D. Disaster risk reduction: Spending where it should count. 2012. Available from: http://www.globalhumanitarianassistance.org/wp-content/uploads/2012/03/GHA-Disaster-Risk-Report.pdf

[46] Government of Zimbabwe. Comprehensive Agricultural Policy Framework (2012-2032) Executive Summary, 2012

[47] Stichting Nederlandse Vrijwilligers (SNV). Rural Agriculture Revitalisation Programme Dairy breeding study report. 2013. Retrieved from: http://www.snv.org/public/cms/sites/default/files/explore/download/zimb abwe_smallholder_dairy_breeding_study_report.pdf [Accessed: 13 November 2015]

[48] Nhlapho B. Zimbabwe grappling with devastating El Nino as world leaders discuss climate change. 2015. Online. Available from: www.voa.zimbabwe.com

[49] Tsikirayi CMR, Makoni E, Matiza J. Analysis of the uptake of agricultural insurance services by the agricultural sector in Zimbabwe. Journal of International Business and Cultural Studies. 2013;1-14

[50] Shield. Shield Health Financing Reform: Who is Covered by Health Insurance Schemes and Which Services Are Used in Tanzania? 2011

[51] Zimnat Lion Insurance. Farming Insurance. 2016. Available from: http://www.zimnatlion.co.zw/business-insurance/farming-insurance/ [Accessed: 16 November 2016]

[52] Mupunga EG, Dube DMJ. Smallholder development programme in resettled and communal areas in Zimbabwe. In: Proceedings of a Workshop on the Future of Livestock Industries in East and Southern Africa Held from 20-23 July in Kadoma, Zimbabwe. Addis Ababa, Ethiopia: ILCA; 1992. pp. 165-172. Available from: http://www.fao.org/Wairdocs/ILRI/x5485E/x5485e0q.htm

Chapter 5

Mind, Consumers, and Dairy: Applying Artificial Intelligence, Mind Genomics, and Predictive Viewpoint Typing

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Abstract

We present a new approach to more deeply understand the mind of consumers with respect to food products, using a combination of artificial intelligence to provide the ideas, Mind Genomics to understand how consumers respond to these ideas, uncovering Mind-Sets, and statistical assignment of new people to these newly uncovered Mind-Sets using the PVI, personal viewpoint identifier. We illustrate the approach in detail with yogurt, and then present data from other studies about yogurt, milk, and cheese, to reveal new knowledge about emergent Mind-Sets for conventional dairy products. The key benefits of the approach are the scope (many ideas from artificial intelligence), discipline (experimental design to uncover what is important), actionability findings, mind-types, speed (within 2 or 3 days), and cost (low because of automation).

Keywords: consumer, conjoint analysis, e-commerce, product development

1. Introduction: the Big Data or fire hose of information

Our twenty-first century world is awash with information. One need only look at the amount of information on the Internet about any topic, and the likelihood is that the number of sites is in the tens of thousands, if not more, at least for topics which are popular. It is not the lack of information which is the bane of our century, but the plethora, metaphorically the fire hose of information.

Our thinking to deal with such an abundance of information is either to shut out most of it, or do some type of directed search for the topic. One cannot absorb the totality of information in a popular subject, nor perhaps even form a reasonable opinion based upon deep knowledge, unless perhaps one has specialized in the topic and has amassed a great deal of information after years of practice. There are of course tools which sift ideas, such as Google® for conventional websites, and Google Scholar® for academic papers. These sifting tools aggregate data "on the fly," presenting the raw material as different sites to explore. One can then use the

Google® tools to get a sense of what is "au courant," although the effort to do so may be more daunting in the execution than in the expectations before the effort is made.

With the foregoing introduction, the next question is how does the novice, whether scientist or simply interested layman, learn about the mind of a consumer toward a specific product? For instance, let the product be "milk." A Google® search of consumer + milk shows a mere 130 million sites. Refining the focus for Consumer Attitudes Regarding Milk, again on Google® revealed 6,280,000 hits. A more focused search, this time for academic papers, on Google Scholar®, for Consumer Attitudes Towards Milk, revealed 90,700 hits. Certainly, enough for a number of PhDs, and for a lifetime of reading, but what about the practical problem of the small, even a start-up company, wanting to develop a new product? The "plethora of choice" in the world of information is simply paralyzing, so that the expeditious answer is to guess, to solicit the advice of an expert, to buy a book of trends in food, to run a focus group, or perhaps to spend a great deal of money developing products and concepts with the full confidence that it MUST BE GOOD [1, 2].

Whether the foregoing picture presents a positive development, a negative development, or perhaps just a development without valence is not the issue. The issue for this chapter is whether one can use the mass of information to understand issues, say in dairy, with these issues relating to the attitudes of consumers. Simply stated, can we create a system to rapidly and profoundly understand the mind of the consumer regarding a specific topic, and, where possible, incorporate the contribution of the "Big Data of Relevant Information?"

2. Surveys, observations, and their limits

For a century now, the norm for understanding subjective reactions to products has been to ask people to talk about these products in focus groups or other qualitative methods [3], and for those who are quantitatively oriented, to ask questions of people in a survey. Often surveys begin with topics about what one does in general, such as food preferences and food habits [4], now evolving down to a momentary survey after a relevant experience to ask 'How did we do?, or 'Would you recommend us to someone with whom you do business?' the now-ubiquitous NPS, (Net Promoter Score), analyzed by [5].

As the amount of information increases, and as companies run surveys about the attitudes and usages of product, whether dairy or other food products, it is becoming increasingly obvious that data are cheap to obtain, but true knowledge of the so-called actionable nature is expensive. By actionable, we mean the use of the data to effect some change, whether that be convincing someone to try or buy a product, or learning how to change the ingredients of a product to increase acceptance. Surveys are limited to the respondent's conscious efforts to answer the interviewer's questions. Often, they require knowledge to which the respondent may not be privy, or may require "politically correct" answers. An example of the former, information to which the respondent is not privy, is what to do to change the fat content of milk, or to make the milk taste like it is full fat. The latter, "politically correct" answers come from the desire to give the correct or socially approved answer. For example, a person who loves whipped cream in great amount on cake as a delicious dessert may simply not describe dessert preferences, or when doing so may consciously or perhaps even unconsciously forget one's lifelong obsession with mountains of whipped cream when allowed to consume it.

3. Changing the paradigm from Big Data and surveys to small experiments

The sheer abundance of data, this so-called "hydrant effect" may seduce one into thinking that the "answers are there" but the reality is that one learns far more from simple experiments. In recent years, author HRM has introduced the new, now more rapidly emergent science of Mind Genomics [6, 7]. The name Mind Genomics is metaphorical. It posits that knowledge about decision-making comes from presenting people with combinations of ideas of different types, measuring their responses, and determining which ideas or sets of ideas (mind-genomes) drive the decision-making. To further the metaphor, each topic area of experience comprises a variety of aspects. The aspects of a topic to which a person attends while making a decision are the so-called "mind genomes." Furthermore, each topic area has a limited set of these mind-genomes, almost mind-alleles, in some sense.

Mind Genomics has already been applied to the dairy world in a number of different, easy-to-do experiments. For example, one study looked at the different ways of making a decision about what a dairy product (yogurt) is worth. Through the Mind Genomics method, it became possible to extract various mind-genomes about yogurt, with each person embodying one of a set of mutually exclusive genomes. The objective of that study was to identify a group of individuals who valued texture or mouthfeel as the basic criterion for decision-making [8].

Other studies of dairy have involved products such as milk, yogurt, cheese and so forth.

4. Positives and negatives of experiments to understand the consumer mind toward dairy

We live in an age of instant gratification, of superficial thinking, of information abundance, and most sadly, a belief that whatever we do has to be made simple, dumbed down. When our focus is to understand the mind of the consumer toward a dairy product, this might mean running a few focus groups to get a "sense" of today's customer, or doing a general survey about dairy using any of the widely available survey platforms like Survey Monkey® [9]. One could also mine the Web for information, and produce a summarized report of trends. The aforementioned approach provides a great deal of information, often delightfully presented in newsletters, at conferences, at webinars. Yet, there is something missing, the translation of the information into product concepts.

One of the most common, traditional methods of using the data is to present the information from these surveys, focus groups, and so forth to the agency and marketing professionals, often called "creatives." It becomes the job of the creative to synthesize the information, and with her or his skill, experience, and insight, to emerge with the final "idea," whether the idea be fully formed or even modestly sketched out.

We are accustomed to experiments in the world of physical features. These experiments may range from a simple change in a product, and the measurement of the consumer response to the product (so-called "cook and look"), all the way up to DOE, Design of Experiment [10]. DOE specifies different combinations of ingredients, and then measures the response to the combination in order to identify what each product ingredient contributes, and how a specific combination performs in a consumer test. DOE is usually in the purview of R&D, and represents a dramatic investment of time and money, but also an increase in the opportunity for a corporate success.

We deal in this chapter with consumer knowledge, ideas. How does one experiment with ideas about dairy? The answer to this question is quite simple. One can present ideas, simple or compound, about a dairy product, and obtain ratings about the ideas. **Figure 1** shows an example of three advertisements about yogurt from Chobani®, presented in the original language, and deconstructed as a preparation for analysis by experimental design:

The choice of concepts in **Figure 1** is simply that. The reasons behind the choice must be left to probing questions asked of those who evaluated the concepts, and/or left to the talented researcher who can "connect the dots" and tell an engaging, and possibly insightful story.

A better way to understand the world of dairy from the mind of the consumer involves experimentation, preferably easy, fast, and inexpensive experimentation that anyone can do [11]. We illustrate the strategy with data from a study

Original ad #1:
Strawberries, plump little hearts grown full and tender, red-ripe and ready-to-love, hidden beneath thick, delicious Chobani® Greek Yogurt.
Mind Genomics format:
Strawberry
Plump little hearts grown full and tender
Red-ripe and ready-to-love
Delicious Greek Yogurt

Original Chobani® ad #2:
New yogurt crunch, milkshakes, and tubes in 11 fun flavors with twice the protein* and nothing artificial
Mind Genomics format:
New yogurt crunch
Milkshake
Fun flavors with twice the protein
No artificial ingredients

Original Chobani® ad #3
Real key lime, ripe and riotous, sweetened and blended in soft, delectable Chobani® Greek Yogurt.
Mind Genomics format:
Real key lime
Sweetened
Soft, delectable texture
Greek yogurt

Figure 1.
Comparison of three text advertisements for Chobani® yogurt taken from the Web (December, 2018), and their deconstruction for study by experimental design (Mind Genomics).

Step	Activity	Rationale
1	Identify the topic	The topic may be product, service, or literally anything where human experience and judgment play a key role.
2	Interrogate the Web and social media using artificial intelligence	The Web and social media present an almost inexhaustible number of ideas. Mine the Web and social media to extract "ideas" in rough form, simple if possible. Consider these to be "nuggets of ideas," a semi-structured reservoir of raw material.
3	Put the Web output aside, and concentrate on the topic, by formulating four questions	The objective is to find four aspects of the topic that can be put as questions which together, and in sequence, *tell a story*. The topic is the description of the product, for this study of yogurt.
4	Edit the four questions, and set them up to be answered	The questions require the user to "think" about the story of what the product is. The questions will never be shown to the respondent. The questions will be used simply to promote creative thought.
5	Answer each question with four answers	Return now to the information extracted by artificial intelligence. With the four questions as a guide, and with the semi-structured reservoir of raw material, provide four answers or phrases for each question. One's mind, one's creative intuitions from the semi-structured reservoir of ideas, and one's ability to craft a sentence allow one to generate the necessary four answers to each of four questions, or sixteen answers in total.
6	Create an introduction for the respondents to read	Make the introduction simple, with little information other than what the study is about, and what the respondent should do. The information will come from the answers to the questions (the messages, the elements).
7	Create a rating scale	The scale comprises a question and an anchored scale (lowest and highest scale points each have a defining phrase). What do you want the respondent to consider when making a judgment? The easiest is an evaluative attribute, such as: *How interested are you in this product?*
8	Select respondents	The entire objective of the exercise is to have respondents judge these ideas. The respondents who participate may come from the corporation's customers, or from a commercial panel. It is always easier to work with panelists who are compensated for their participation. The fastest, easiest, and often the most productive way is to work with a commercial company.
9	Get classification information	Find out age, and gender. Put in a third classification question dealing with the topic. The APP used here is limited to three classification questions to make the system quick and inexpensive to execute.
10	Present the respondent with 24 vignettes, one after another	Each respondent evaluates a UNIQUE SET OF 24 VIGNETTES. This unique set is important. It means that increasing the number of respondents allows the researcher to test more of the "space of the combinations" rather than simply testing the same combinations again and again.
11	Collect the rating from each vignette and measure response time	The response time is the time from the presentation of the vignette on the screen to the response. The time is measured in seconds.
12	Ask the respondent another question, open-ended, about a relevant aspect of the topic	Optional, to obtain more information from the respondent about her or his feelings.
13	Transform the 9-point ratings to binary	For the typical, most-used, 9-point scale, convert the rating of 1–6 to 0. Convert the rating of 7–9 to 100. Then add a very small random number to the now-converted value of 0 or 100, respectively. The reason for the transformation is that although the rating scale is easy to use, it is not clear what a scale value means. It is a lot easier to use a binary scale. The key is how to bisect the 9-point rating scale. We are somewhat stringent, with "no" corresponding to the bottom 2/3 of the scale, and "yes" corresponding to the top 1/3 of the scale.

Step	Activity	Rationale
14	At the level of the individual respondent, use OLS (ordinary least-squares) regression to relate the presence/absence of the 16 answers to the binary ratings (0/100)	The vignettes were constructed according to a basic experimental design. The design was permuted for each respondent. The experimental design allows us to estimate the coefficients of the model for each respondent. The equation created is of the form: Binary Rating = $k_0 + k_1(A1) + k_2(A2) \dots k_{16}(D4)$. For other, bigger designs, also created in this fashion, using a permuted individual-level design, there may be more questions and more answers per question. The mathematics is precisely the same. The only difference is the number of coefficients. There is one coefficient for each answer.
15	OLS relates the presence/absence of the 16 answers to the response time	Using the same mathematics, create another model for each respondent, this time using response time as the dependent variable. Prepare the data by recoding any response time of 30 seconds or over as 30 seconds because the longer time probably represents an interruption in the experiment. The equation does not have the additive constant, k_0. We write it as follows: Time (seconds) = $k_1(A1) + k2(A2) \dots k_{16}(D4)$.
16	The unit of analysis is the individual coefficient	By applying OLS regression to the data from each respondent, we ensure that each respondent generates an individual set of 16 coefficients, and for interest, an additive constant as well. We use that coefficient as the basis of understanding the pattern of responses for each participant, as well as averaging the coefficient across subgroups to understand the average of the subgroup, and thus the pattern of their thinking about the topic.
17	The coefficients tell us about how the respondents react to individual elements	We can combine the additive constant with up to four answers or elements and add their values to estimate the performance of the combination. Recall from above (#16) that the additive model is written as: Binary Rating = $k_0 + k_1(A1) + k_2(A2) \dots k_{16}(D4)$. The additive constant, k_0, tells us the likely rating on the scale of 0–100 that would be achieved if the vignette had no elements, no answers. The coefficient tells us the contribution of each element or answer. Each of the 16 answers has an average coefficient. Positive coefficients mean that adding the answer to a combination or vignette increases the proportion of respondents who rate the concept 7–9. A negative coefficient means that adding the answer to a combination or a concept decreases the proportion of respondents who rate the concepts 7–9. It is not that they do not like the idea. It is just that the element is not a particularly strong positive. We consider results from base sizes as few as 8–10 respondents. Below that base for a subgroup, the average coefficient is not stable.
18	Combine groups of respondents based on any criteria	To find subgroups, we simply combine the coefficients from the people who fall into the group. This could be gender, age, pattern of usage, etc. Then, across the respondents selected for the subgroup, average their respective additive constants, and corresponding coefficients, to estimate group performance. Alternatively, we can simply put raw data together for all the relevant respondents in a subgroup, and run one OLS regression. This is called the Grand Model. The parameters of the Grand Model typically correlate highly with the corresponding average parameters estimated by averaging the individual models.
19	Previous studies suggest norms	When the coefficient is … here is how to interpret +15 or higher major positive +10 to +15 strong positive +5 to +10 positive 0 to +5 does not hurt, but not important 0 to −5 negative, only slightly damaging −5 to −10 negative, could be damaging −10 or lower strong negative

Step	Activity	Rationale
20	Within any topic, Mind Genomics allows us to uncover basic groups of responses, so-called Mind-Sets	These might be considered the basic mental alleles of judgment of a topic. They are not exhaustive, but suggest groups with different thoughts about what is important and relevant (positive or negative) versus irrelevant.
21	Use conventional statistics (clustering) to uncover Mind-Sets, but judgment to name them	To find Mind-Sets, we array the coefficients from our respondents (but not the additive constant), creating a matrix. The columns are the elements (our 16 elements). The rows are the respondents (our 50 respondents). We compute a measure of distance between each pair of respondents, using an accepted distance measure. In our case, we use the value (1-Pearson R). The Pearson R, or correlation varies from a high of +1 (perfect linear relation, meaning a distance of 0 between the two respondents), down to a low of −1 (perfect inverse relation, meaning a distance of 2 between the two respondents). Clustering then reveals non-overlapping groups of meaningfully different respondents, showing different Mind-Sets. We choose the fewest number of clusters or Mind-Sets (parsimony), such that these Mind-Sets tell a meaningful story (interpretability).
22	Create a set of questions from the experiment, the pattern of answers to which assigns a new person to one of the Mind-Sets uncovered in the experiment	The set of answers in the study (the original set of 16) now are filtered to identify which answers most efficiently differentiate among Mind-Sets. The PVI, personal viewpoint identifier, emerging from the experiment typically comprises 3–7 such answers from the original 16, now recast as statements. The different answers (aforementioned 3–7) are presented in random order for each person to be mind-typed and assigned to one of the Mind-Sets. The person to be assigned either agrees with the statement or disagrees with the statement (or feels the statement is important or unimportant). Thus, the response is binary, no/yes, unimportant/important, disagree/agree. The pattern of responses assigns the person to one of the Mind-Sets, the "best guess" assignment.

Table 1.
The paradigm explicated using yogurt.

that required a total of 6 hours, done at a very low cost, dealing with yogurt. The emphasis on speed, cost, and simplicity is important for the tenor of the chapter. Our goal is to present a new paradigm, more powerful than other previous approaches, as well as far faster, and significantly more economical, all leitmotifs for today, as of this writing (December, 2018). The strategy is very simple, encapsulated in **Table 1**.

5. Toward a new paradigm: front to back Mind Genomics experiment with a dairy product, yogurt

A good way to understand the features of the paradigm and what it delivers to the user comes through the demonstration with a common product that can be moderately modified, with that innovation driven by the consumer requirements. This is the typical situation, wherein there is no major technical innovation, but there is the corporate need to offer something new and attractive. The ingoing assumption is that the "new product" is somewhere "out in the ether." The features of the new product must be discovered, and not slogans, but real ideas. The effort may be too slow or cumbersome when fighting against other internal priorities, or when the assignment must be to an outside, not-necessarily quickly responsive organization. Nor, in fact, is there the desire to wait until some start-up corporation develops a product, and then "snatch up" the corporation, making up by acquisition what one lacks in creation and innovation.

Our case history here is yogurt, although the precise steps can be used for virtually any dairy product, any food product, and indeed any product or service about which people write and talk. The specifics for yogurt are thus meant only as didactic examples.

The specific study on which we elaborate began on December 19, 2018, and finished on December 23, 2018. Of that time, the first 2 days were devoted to refining an existing software which scoured the Internet, discovering and reporting on trends, with these trends specified to be in the food industry. On December 23, we ran the study, and emerged with the results. After the holiday period, on January 4, 2019, we developed the PVI, the personal viewpoint identifier. Altogether, the paradigm, from knowledge development to testing to the personal viewpoint identifier can be said to have required approximately 48 hours of real time, taking into account the development time, as well as the disrupting time respectively. The objective is to show how to "do it" by actually doing it. In the elaboration, we present the different steps following the outline in **Table 1**.

6. The raw material

Figure 2 shows an example of the summary information for "Yogurt" yielded by the artificial intelligence system created by authors Choudhuri and Upreti and named "SamanthaSM" for this early stage. **Figures 3** and **4** show examples of the output of Samantha, using the artificial intelligence system.

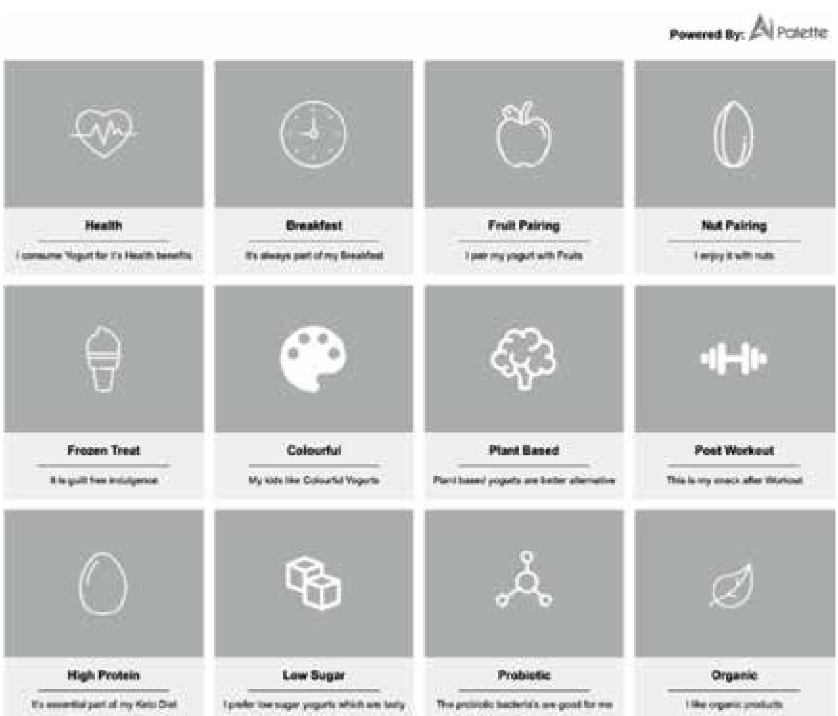

Figure 2.
The matrix of information about the products. The matrix emerges from the artificial intelligence platform, "SamanthaSM," previously designed to deal with the entire vertical of food and beverage.

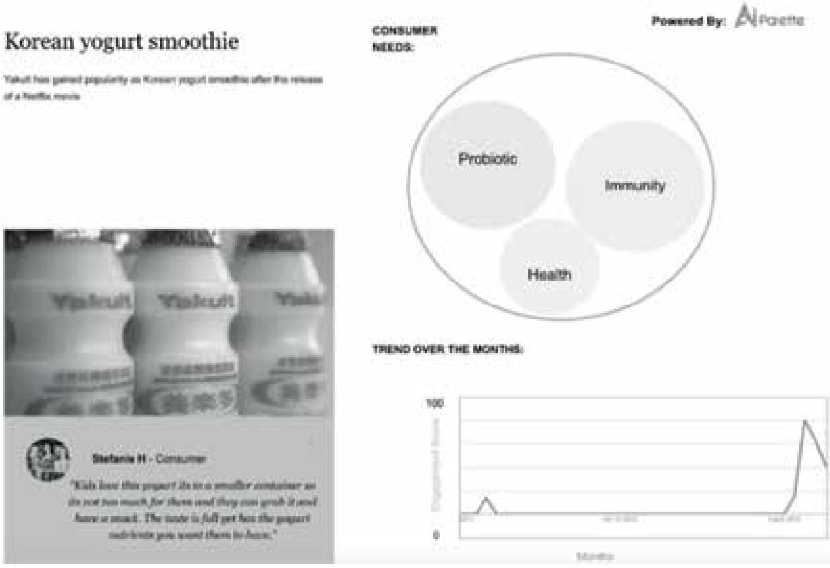

Figure 3.
Korean smoothie deconstructed by SamanthaSM.

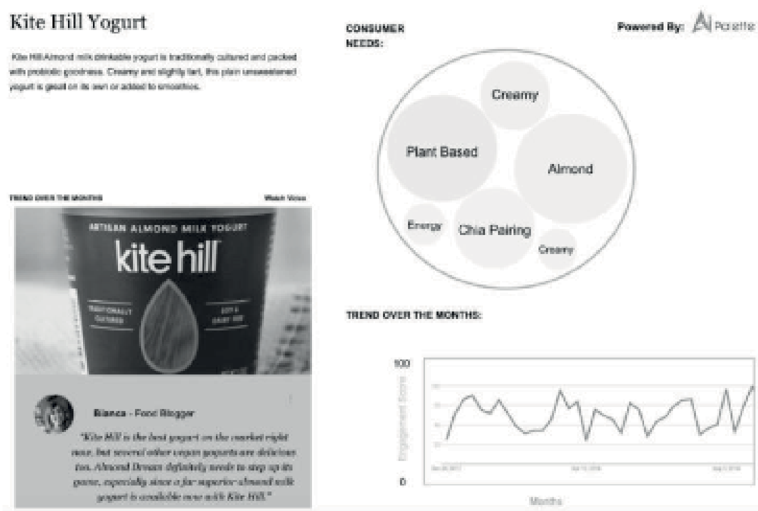

Figure 4.
A health-oriented yogurt deconstructed by SamanthaSM.

Figure 2, shows a matrix of information about the products. This matrix, with circles and a short phrase, gives a sense of the different ideas. It is important to note that the effort from artificial intelligence is not to create the final questions and answers, but rather to provide hints, suggestions, from which the questions and answers are crafted. We will see the nature of the crafting later.

7. Moving from raw material to questions and answers

Mind Genomics works by presenting the respondents with combinations of ideas, messages, or in our case, combinations of answers to four questions created from the raw material shown in part in **Figures 1**–**3**. As we noted earlier, the role of artificial

	Question A—What type of product is this?
A1	A frozen yogurt
A2	A Greek yogurt
A3	A yogurt smoothie
A4	A plain yogurt
	Question B—What does this product deliver in terms of sensates?
B1	Flavorful fruit enhances the yogurt
B2	The yogurt has a colorful, picturesque appearance
B3	The texture of the yogurt is creamy and delicate
B4	The rich taste compliments the appetizing aroma
	Question C—When would you eat this yogurt?
C1	For those on the move and in need of a quick breakfast
C2	Complements a meal as the perfect side
C3	Perfect as a natural energy boost
C4	Improves recovery after daily exercise
	Question D—What are the health benefits of this yogurt?
D1	Provides your body with the protein it craves
D2	Low sugar… without sacrificing great taste
D3	Probiotic-rich and immune system boosting
D4	Only the most natural and organic ingredients

Table 2.
The four questions and four answers from each question, created by inspecting the information provided by the artificial intelligence platform, and generating the relevant statements to be used in the actual field execution.

intelligence, and particularly the SamanthaSM platform, is to present suggestions that the researcher can use to elaborate. The output from the artificial intelligence system comprises both a set of words in **Figure 2** to "jog the mind," as well as links to deeper information (**Figures 3** and **4**). Thus, the Mind Genomics system gives room for suggested topics, as well as for the human elaboration of those topics.

Table 2 presents the set of four questions, extracted from the information provided by the artificial intelligence platform, and then elaborated and edited to move from information to questions. Each question, in turn, generates four answers, or more correctly, the researcher provides four answers to each question. The answers may be taken directly from the information provided by the artificial intelligence platform, or the answers may be polished and edited information, or perhaps even new ideas sparked by the information provided, by not actually part of the information provided. The reality is that it does not really matter where the information comes from. The Mind Genomics effort is attempting to discover "what works." The information provided to it is the raw material. The goal is to get the best information and identify "what works."

8. Knowledge from responses to mixtures of answers—the contribution of experimental design

One could take the 16 answers in **Table 2** and rate each of the ideas on a scale of interest. Presenting the answers one at a time and obtaining an answer is the survey method, widely used, but unable to spark the creation of a new product idea in the way it is structured. By presenting the answers one at a time, and then requiring the respondent to rate each idea alone, we are left with ratings of single ideas, but no idea of how ideas interact with and compete with each other, as they drive interest. The respondent may also change the criterion of judgment, judging healthful ingredients more leniently, and the more indulgent features more stringently.

A potentially more productive way mixes and matches the answers, creating vignettes. The answers become the building blocks. Rather than building one answer at a time, starting with the most popular, we create combinations of answers using a recipe book (experimental design). The responses to the mixtures of answers help us understand the performance of the single elements. We do that by deconstructing the response to a blend, our mixture of answers, to the part-worth contribution of each answer. This notion was developed extensively by Norman Anderson [12], formalized as the method of conjoint measurement [13], popularized in business and academic circles by Professor Paul Green of The Wharton School of Business of the University of Pennsylvania [14, 15], and finally expanded, and made available worldwide as a method of knowledge building by author HRM [7].

9. The 4 × 4 design used in mind genomics

Mind Genomics works with various experimental designs. For these studies, we work with the so-called 4 × 4 design, namely four questions, each question requiring four answers. **Table 2** showed the raw materials, the answers or features (elements, ideas, messages) for this study. The experimental design for the 4 × 4 design comprises 24 different combinations. Each of the 16 answers or elements is statistically independent of every other answer, allowing us to analyze the data by the method of OLS (ordinary least-square regression), discussed later.

Table 3 shows the first six vignettes or test combinations for one respondent, along with the 9-point rating, the transformed value for the rating, and the response time for that vignette (test combination). Each respondent evaluates a totally different set of vignettes. The underlying experimental design is the same in a mathematical sense, but the actual vignettes differ, because a permutation scheme systematically varies the pairs of elements which appear together.

10. The study setup by the researcher and the respondent experience

At its basic level, the Mind Genomics study is an experiment, albeit couched in the form of a survey. The researcher systematically varies the stimulus inputs, the answers, according to the experiment design (**Table 3**), records the respondent's rating as well as time of response, and then analyzes the results. **Figure 5** shows what the respondent sees (test vignette) when using a smartphone. The same vignette can be presented in a slightly different configuration to fit the screen of a personal computer or a tablet.

The typical Mind Genomics experiment with BimiLeap® takes approximately 4–5 minutes from start to finish. Many respondents begin with the typical strategy of trying to be "correct." The respondent may spend more time at the start than at the end, reading the vignettes, in order to make sure that they have gotten all the relevant information. By the time the respondent reaches second, and certainly the third vignette, however, this effort begins to subside, and the respondent answers, almost automatically, at an intuitive level, the System 1 of Nobel Laureate Daniel Kahneman [16].

Order	1	2	3	4	5	6
A1	0	0	0	1	0	1
A2	0	0	0	0	0	0
A3	0	0	1	0	1	0
A4	0	0	0	0	0	0
B1	0	0	0	0	1	1
B2	0	0	0	0	0	0
B3	1	1	0	0	0	0
B4	0	0	1	1	0	0
C1	1	0	1	0	1	0
C2	0	1	0	1	0	0
C3	0	0	0	0	0	0
C4	0	0	0	0	0	1
D1	1	0	0	0	0	0
D2	0	0	0	1	1	0
D3	0	0	1	0	0	0
D4	0	1	0	0	0	1
Rating	7	7	8	8	8	5
Binary	101	100	100	101	101	0
Res Time	13	10	6	5	5	3

Table 3.
The first six vignettes for one respondent. The 4 × 4 design prescribes 24 vignettes of precise design in terms of the elements which each vignette comprises.

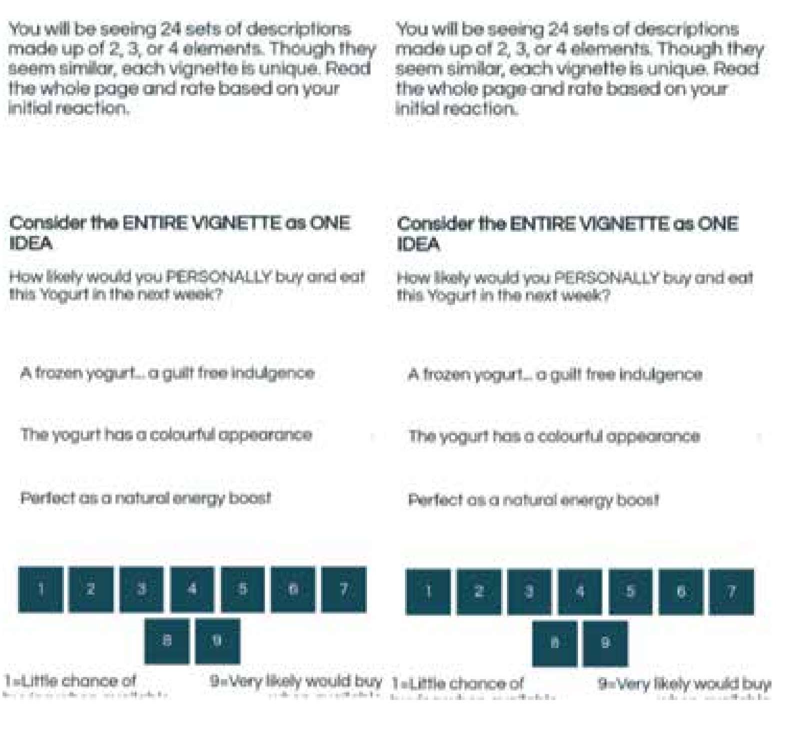

Figure 5.
The respondent experience when using a smartphone with a small screen.

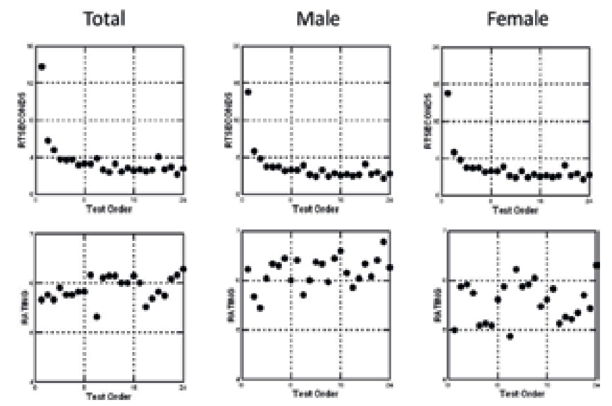

Figure 6.
The average time in seconds needed for a respondent to read a vignette and assign a rating (top row of graphs), and the average rating assigned to the test vignette (bottom row of graphs.).

Figure 6 shows the external dynamics of the experiment. The top set of figures shows the average response time in seconds, by position of the vignette. We see that whether we deal with the Total Panel, with males, or with females, the pattern is virtually the same. The average response time after the first vignette tested drops to a constant level. Despite the long time and the extensive number of vignettes, respondents still seem to vary their ratings.

11. What drives interest in yogurt: results from our study

Up to now, we have focused on the setup and execution of the study. The more interesting part of the study comes from the discovery of just how the answers, the stimulus inputs under the researcher's control, "drive" the response, in this case interest. In this section, we look at the results from our experiment with 50 respondents. We will look at the additive constant to get a sense of baseline interest, then at the coefficients to see which elements or answers drive interest, and then search for Mind-Sets, groups of ideas which "move together." Each of our 50 respondents will be assigned to a Mind-Set based upon the pattern of coefficients. **Table 4** shows the results.

a. Total Panel shows an additive constant of 56, meaning that in the absence of any elements in the vignette, we expect 56% of the answers to be ratings of 7–9. Basically, yogurt is liked. It will be up to the elements to drive liking much higher.

b. The "Total Panel," with all 50 respondents, shows NO very strong elements. This means that if we continue to try these types of ideas, it is likely that for the general population nothing will work, or when some element works, it will be probably by accident.

c. The answer is dividing the respondents into Mind-Sets. The Mind-Sets are selected from the mathematical clustering to "make sense." The computer only divides the respondents by the pattern of coefficients. It is the researcher and the marketer who must make sense of the Mind-Sets.

d. Mind-Set MS1: Modestly interested in yogurt (additive constant 37), but interested in the type of yogurt, especially high protein and convenient. They may like yogurt for its probiotic qualities. We could call these the health-through-a good-tasting-food.

e. Mind-Set MS2: A yogurt aficionado (higher additive constant of 58), likes the multisensory appeal of yogurt.

f. Mind-Set MS3: A yogurt aficionado (higher additive constant of 48), but probably looking for a low-calorie snack.

The prudent developer might well repeat this step 3–4 times, with different sampling of ideas from SamanthaSM, and with new populations of respondents, perhaps retaining the strong performing ideas, for a final test (e.g., step #5) comprising only strong performing answers or elements which have proved themselves.

	Group	**TOT**	**MS1**	**MS2**	**MS3**
	Tentative name		Health & good taste	Multisensory	Low-calorie snack
	Base size	50	22	13	15
	Additive constant	56	37	58	58
	Question A: Type				
A1	A frozen yogurt… a guilt-free indulgence	-3	9	8	−30
A2	A Greek yogurt… high in protein	−3	**14**	4	−34
A3	A yogurt smoothie… no spoon required	−4	**17**	−1	−37
A4	A plain yogurt… versatile, customizable	−7	8	1	−37
	Question B: Traits				
B1	Flavorful fruit enhances the yogurt… taste and health	4	−3	**25**	−4
B2	The yogurt has a colorful appearance	1	−5	**22**	−8
B3	Nutrient-rich nuts improve the texture and flavor-profile of the yogurt	1	−3	**11**	−3
B4	The yogurt is plant-based… a better alternative	−2	−6	**22**	−16
	Question C: Situation				
C3	Perfect as a natural energy boost	0	5	−3	−5
C2	A healthy meal and snack alternative	−1	−2	−6	4
C4	Improves recovery after daily exercise	−1	2	−9	1
C1	For those in need of a quick breakfast	−6	−8	−12	0
	Question D: Benefit				
D3	Probiotic-rich… immune system boosting	2	**15**	−14	−3
D2	Low sugar… without sacrificing great taste	0	9	−28	**10**
D4	Only the most natural and organic ingredients	−1	9	−15	−5
D1	Provides your body with the protein it craves… essential for keto diets	−4	8	−21	−6

Table 4.
The results from the study, showing the coefficients for interest (binary transform) both from the Total Panel (ToT), and from the three complementary Mind-Sets (MS1, MS2, MS3).

12. Response times and their relation to Mind-Sets

We now turn to the second important variable, response time. The BimiLeap® APP from Mind Genomics measured the number of seconds from the presentation of the vignette on the screen to the response. The analysis deconstructs the response time in seconds into the part-worth contribution of each element in the vignette. The model does not have an additive constant, so that the response time is "0" in the absence of any elements. Furthermore, **Figure 6** (top panels) suggests that the response time to the first vignette should be discarded. That response time is longer than the other response times, probably because when making that first rating, the respondent is not accustomed to the procedure, and there may be some issues both with eye-hand coordination, and with using the scale. By the second vignette, however, the response time is quite stable.

	Response times from vignettes 2–24	TOT	MS1	MS2	MS3
			Health and good taste	Multisensory	Low-calorie snack
	Question A: Type				
A2	A Greek yogurt... high in protein	0.7	1.1	0.9	**0.1**
A3	A yogurt smoothie... no spoon required	1.0	1.1	0.9	0.9
A4	A plain yogurt... versatile, customizable	1.0	1.2	0.8	1.0
A1	A frozen yogurt... a guilt-free indulgence	1.0	1.3	0.8	0.9
	Question B: Traits				
B1	Flavorful fruit enhances the yogurt... taste and health	0.9	1.0	0.9	0.7
B3	Nutrient-rich nuts improve the texture and flavor-profile of the yogurt	1.0	1.5	**0.5**	0.7
B4	The yogurt is plant-based... a better alternative	1.0	1.8	**0.2**	0.6
B2	The yogurt has a colorful appearance	1.2	1.8	**0.1**	1.0
	Question C: Situation				
C2	A healthy meal and snack alternative	0.8	**0.4**	0.7	1.5
C4	Improves recovery after daily exercise	1.0	0.5	1.3	1.5
C3	Perfect as a natural energy boost	1.1	0.7	1.6	1.0
C1	For those in need of a quick breakfast	1.2	0.9	1.6	1.5
	Question D: Benefit				
D3	Probiotic-rich... immune system boosting	**0.3**	**−0.2**	**−0.3**	1.4
D1	Provides your body with the protein it craves... essential for keto diets	0.5	**0.1**	**0.4**	1.4
D2	Low sugar... without sacrificing great taste	0.7	0.9	**0.5**	0.7
D4	Only the most natural and organic ingredients	1.3	1.4	0.7	1.6

Table 5.
Coefficients for response time both from the Total Panel (TOT), and from the three complementary Mind-Sets (MS1, MS2, MS3) emerging from the rating question.

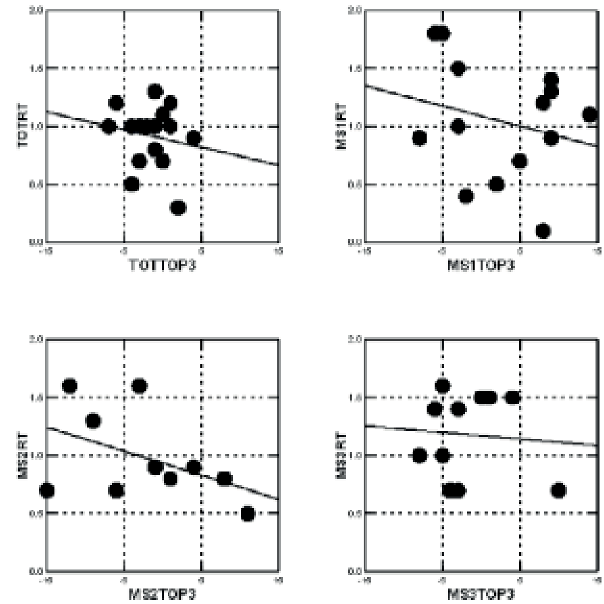

Figure 7.
Scatterplot showing the relation between the coefficient for response time (ordinate) and the coefficient for interest (abscissa). The patterns are shown for the Total Panel, and for the three Mind-Sets, respectively.

Our objective here is to discover whether the 16 answers each generate the same response time. The way to do that is again by OLS regression. This time, however, we put all the relevant data into one set, and estimate one "grand" regression model for that relevant data. By "relevant," we mean first eliminating ALL data from the first vignette (order #1), no matter who the respondent happens to be. We then either divide the data into three groups, depending upon the Mind-Set of the respondent, allowing us to estimate the response time per element for each Mind-Set, or we look at all the data in one group for Total Panel. We run the Grand Models for this analysis, rather than running the individual-level models.

Table 5 shows the coefficients for response time estimated for each of the 16 elements, both for the Total Panel and, respectively, for the three Mind-Sets generated from the ratings assigned to the vignettes. **Table 5** shows clear differences in estimated response time (RT) across the elements, and across the Mind-Sets.

When we plot response time against interest, with the points corresponding to the 16 coefficients for the 16 elements, **Figure 7** suggests differences in response time may not strongly co-vary with the interest in the message estimated from the rating. That is, more interesting messages or elements are not necessarily responded to more quickly. *This lack of strong co-variation between interest and response time differs from what has been recently uncovered by author HRM in a study of the same type, dealing with a political issue, the Russian-Ukrainian conflict of 2018, rather than yogurt*. It may well be that the studies of RT require topics which are involving. Yogurt simply may be not particularly involving even though the data may make sense.

13. Finding these respondents in the population

Our efforts to create a new yogurt concept through experimental design (BimiLeap®), powered by access to trends through artificial intelligence (SamanthaSM) have uncovered a new way to understand a product category and prepare to create new concepts. We see clearly from the data in **Table 4** as well as from the array of previous studies on dairy that people perceive the features of a dairy product in different ways, at least in terms of what they consider to be interesting and important. Our identification of the mental genomes, these alleles of preference, pertains only to the respondents whom we tested, generally small groups of consumers from easy, affordable panels. How do we generalize our findings, either to discovering the distribution of these basic Mind-Sets in the population or, more importantly, discovering individuals who are members of these Mind-Sets, and who can be further studied? The further studies may be as simple as their preferences for concepts created for the product (e.g., yogurt products), on to purchase and consumption patterns, and even beyond to possible health and genetic correlates of segment membership? One approach to predicting Mind-Set membership looks at the pattern of coefficients for the Mind-Sets (**Table 4**), and selects elements showing the greatest differentiating power, that is, the biggest difference for the average panelist. Each selected element is then edited to become a question, to be answered NO or YES, or some other appropriate pair of responses for the same type of binary decision. The questions are incorporated into a short questionnaire. The pattern of responses shows the Mind-Set to which the respondent probably belongs. The feedback to the respondent or to a marketing company using the data appears in **Figure 6**, in the three right panels. The personal viewpoint identifier is easy to create using summary data, is quick to administer, and can be configured as either a "fun" tool to engage customers, or as a more serious tool to understand the mind of the consumer. From one study, one can proceed to type up to the millions of respondents, should one wish to study entire populations. For this study on yogurt, the personal viewpoint identifier is shown in demonstration form in this link: http://162.243.165.37:3838/TT04.

14. Five-year prospects: trend definition, product design, mass mind-typing, personalization

As presented here, the approach we present begins with a combination of social data analysis and experimental science, moving on to new vistas. These vistas include a new way of exploring ideas, uncovering possibly new-to-the-world mind-genomes, and finally, understanding how neurophysiological processes indicated by response time co-vary with interest in the product. We now move beyond the data to suggest opportunities and applications, some of which are already in their nascent stages, and some of which are easily done, but simply have not been implemented.

Trend definition: The objective of trend spotting is to identify general patterns of what is happening, usually from an exploration of websites and conversations, and their distillation into general patterns. The patterns provide broad patterns, not specifics. Thus, for dairy, we might find a trend emerging for cultured milk products like kefir, combined with new flavors and interesting incorporations, such as chia seeds. The trend spotter may guess about the nature of this trend. What would happen if the new ideas could be incorporated in a Mind Genomics study, with the respondents asked to rate the likelihood of each vignette as an emerging trend? The answers would range from absolutely never to current to approximately a year or a two in the future. In this case, the trend is defined not so much by what one observes as by a combination of that which is observed, with some conscious elaborations of what might be.

Product design: This chapter presents the Mind Genomics as an effort to deconstruct the response to individual features of dairy products based upon the response to vignettes. One can also look at the Mind Genomics as a "Mixmaster" of ideas, whether these ideas or elements be based upon yogurt, upon dairy in general, or even other foods and situations. When these elements from disparate sources are combined, elements not only for yogurt, for example, the outcome is a new set of possible products. The promising ideas can be combined. When, for the most part, the ideas from different areas really do not work together, the ratings for the combinations will be low, and there will not be any strong performing elements, suggesting that the raw materials simply do not work together.

Perhaps the most important contribution of Mind Genomics is to combine profound knowledge of a person's interest in dairy products with both the ability to guide the person to eat better, and to understand how preferences for dairy co-vary with behavior. The full elaboration of the social use of Mind Genomics for health issues and dairy awaits the new generation of researchers, interest in dairy, in health, and in commerce, respectively. We have presented early indications and of these new developments.

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References

[1] Govindarajan V, Trimble C. Strategic innovation and the science of learning. MIT Sloan Management Review. 2004;**45**:67

[2] van Kleef E, van Trijp HCM, Luning P. Consumer research in the early stages of new product development: A critical review of methods and techniques. Food Quality and Preference 2005;16(3): 181-201. Available from: http://www.sciencedirect.com/science/article/pii/S0950329304000886

[3] Esmerino EA, Ferraz JP, Filho ERT, Pinto LPF, Freitas MQ, Cruz AG, et al. Consumers' perceptions toward 3 different fermented dairy products: Insights from focus groups, word association, and projective mapping. Journal of Dairy Science. 2017;**100**(11):8849-8860. Available from: http://www.sciencedirect.com/science/article/pii/S0022030217308159

[4] Lusk JL. Consumer research with Big Data: Applications from the Food Demand Survey (FooDS). American Journal of Agricultural Economics. 2017;**99**(2): 303-320. DOI: 10.1093/ajae/aaw110

[5] Artz M. NPS—The one measure you really need to grow? Controlling and Management Review. 2017;**61**(1):32-38. DOI: 10.1007/s12176-017-0002-x

[6] Moskowitz HR, Gofman A, Beckley J, Ashman H. Founding a new science: Mind genomics. Journal of Sensory Studies. 2006;**21**(3):266-307. DOI: 10.1111/j.1745-459X.2004.00066.x

[7] Moskowitz H, Gofman A. Selling Blue Elephants: How to Make Great Products That People Want Before They Even Know They Want Them. First. Philadelphia, Pennsylvania: Wharton School Publishing; 2007

[8] Moskowitz HR. Mind genomics® and texture. In: Food Texture Design and Optimization. John Wiley & Sons, Ltd; 2014. pp. 342-377. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1002/9781118765616.ch14

[9] Waclawski E. How I use it: Survey monkey. Occupational Medicine. 2012; **62**(6):477. DOI: 10.1093/occmed/kqs075

[10] Box GEP, Hunter JS, Hunter WG. Statistics for Experimenters: Design, Innovation, and Discovery. 2nd ed. Hoboken, NJ: Wiley-Interscience; 2005

[11] Moskowitz HR, Gofman A, Itty B, Katz R, Manchaiah M, Ma Z. Rapid, inexpensive, actionable concept generation and optimization: The use and promise of self-authoring conjoint analysis for the food service industry. Food Service Technology. 2001;**1**(3):149-167

[12] Anderson NH. Foundations of Information Integration Theory. Cambridge, Massachusetts: Academic Press; 1981

[13] Luce RD, Tukey JW. Simultaneous conjoint measurement: A new type of fundamental measurement. The Journal of Mathematical Psychology. 1964;**1**(1):1-27. Available from: http://www.sciencedirect.com/science/article/pii/002224966490015X

[14] Green PE, Rao VR. Conjoint measurement for quantifying judgmental data. Journal of Marketing Research. 1971;**8**(3):355-363. Available from: http://www.jstor.org/stable/3149575

[15] Green PE, Srinivasan V. Conjoint analysis in marketing: New developments with implications for research and practice. Journal of Marketing. 1990;**54**(4):3-19. Available from: http://www.jstor.org/stable/1251756

[16] Kahneman D. Thinking, Fast and Slow. New York, NY, USA: Farrar, Straus and Giroux; 2011. Available from: https://books.google.hu/books?id=ZuKTvERuPG8C

Section 4

Functional Dairy Food Products

Chapter 6

Development of Functional Cheeses with Fructooligosaccharides

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Abstract

Cheese is a food of great consumption in the world; however, some aspects related to its fat content and the possibility of incorporating fiber represent interesting challenges for the dairy industry. In this sense, fructooligosaccharides (FOS), as inulin and agave fructans, exhibit valuable nutritional and functional attributes that can be used as supplements as soluble fiber or as macronutrient substitutes. In this chapter, the study of the development of soft and cream cheeses was performed to determine the operating conditions that allow obtaining products with beneficial health properties taking advantage of the characteristics of this carbohydrate. The skim milk was produced by ultrafiltration, and all the products were characterized physicochemically, including determinations of color, texture, and sensory analysis. The cheeses obtained were of high moisture, >45% (w/w), and reduced fat content (10–25% w/w), including a high protein concentration. The presence of fructans did not significantly modify the texture and appearance of the developed products, but its retention in the matrix was maximal in the case of spreadable cream cheeses containing inulin. Considering the health benefits of fructans and their abundance, this development could represent an innovation for dairy industry.

Keywords: functional cheese, fructans, microfiltration membranes

1. Introduction

Cheeses are high nutritional value foods and with great market demand, outstanding among other products as it has high biological value proteins with a very favorable amino acid profile and good digestibility.

Argentine is the seventh largest producer of cheese in the world in a relatively stable market, where consumption per capita is 12 kilos per year. It is reported that half of the country's milk is destined for cheese processing. It is about 500 thousand tons and is distributed 50% to make soft cheeses, 35% for semihard, and 15% for hard. Between 70 and 75% of the production is commercialized in the domestic market: approximately 13,000 dairies supply about 870 establishments that make cheeses . In Latin America, Argentina is the country with the highest consumption of cheeses.

However, cheese has restrictions on its consumption due to its high content of calories and highly saturated fats and therefore with a potential risk to health.

Indeed, one of the market trends is the production of cheeses with reduced fat content to minimize the negative effects of lipids in the diet. With the purpose of texturally compensating the product, the addition of fructans such as inulin or agave fructans has been studied [1, 2].

Fructans are nondigestible carbohydrates present in many vegetables, fruits, and cereals. They are widely used as ingredients of functional food since they have beneficial effects on health as prebiotics. Dietary prebiotics are typically nondigestible fiber compounds that pass undigested through the upper part of the gastrointestinal tract and stimulate the growth or activity of advantageous bacteria that colonize the large bowel by acting as substrate for them. They supply dietary fiber, hypoglycemic, low calorie value, providing a better bioavailability of calcium and magnesium and improving intestinal iron absorption [3, 4]. Bosscher et al. [5] reported that the consumption of fructans in humans increases calcium absorption, improving bone mineral content and density. Besides, there are promising evidences of its performance in the regulation of lipid parameter, reduction of cancer risk, reinforcement of the immune response, and protection against bowel disorders.

According to the American Dietetic Association (ADA), it is usually understood under the name of functional food any food or potentially healthy ingredient that can provide health benefits beyond the traditional nutrients it contains.

Hippócrates, a Greek doctor more than 2000 years ago, left in his legacy a mythical phrase "That food be your medicine and medicine your food" and, although he did not use the term functional food, was implicitly referring to the consumption of certain foods that could help prevent diseases. Located in the twenty-first century, this philosophy of "food as medicine" is the basis of the paradigm of functional foods. Regarding the abovementioned, the challenge of achieving functional consumer cheeses is undoubtedly an interesting aspect for the dairy industry.

The basic technology of manufacturing a cheese is similar for almost all varieties, but it is important to mention that relatively small changes in the processing conditions give rise to important differences in the final cheese. In general these differences lie in the use of different types of ferments, in variations in cooking temperatures, curd cut, cheese grain size, brine and ripening times, and other technological conditions. Furthermore, in the case that different ingredients that provide the desired functionality are used, it also leads to really different products.

The membrane technology is increasingly employed for dairy treatment [6]. The development of membrane materials, equipment, and studies of fouling and cleaning of membranes increases their applications. These aspects are addressed in this chapter with the purpose of achieving a functional food from natural resources also using the membrane technology to perform the skimming of the raw material.

In this chapter, results about the incorporation of fructans in cheesemaking matrices are described in order to obtain reduced fat cheese-containing compounds that behave like probiotics and act as dietary fiber.

2. Materials and methods

2.1 Raw materials

The elaboration of each of the samples of cheese studied was made from 2500 ml of raw milk from a dairy farm in the province of San Luis and with milk sample of an establishment of the province of Buenos Aires. Before starting the cheese manufacturing process, a fat reduction was carried out in order to obtain a product that is low in fat and, therefore, healthier. For this purpose, a procedure using membrane technology was developed, as will be explained later.

The following compounds were added to all cheese samples per liter of milk: ferment consisting of lactic acid bacteria that allow the acidification and coagulation of milk, inhibiting, in addition, the development of other unwanted microorganisms. There are different types of ferments, and the one chosen depends on the type of cheese. In this work homofermentative mesophyll ferment, lyophilized direct inoculation composed of *Lactococcus lactis* subsp. *lactis* and *Lactococcus lactis* subsp. *cremoris* (CHR Hansen R-704), was used. Although the ferment is a direct inoculation, it is convenient to leave it pre- mature for 30 min in a little amount of milk at an optimum temperature of 34 ± 2°C before adding it to the rest of the milk. The working temperature was also maintained at 32–37°C during a large part of the processing to allow the action of the ferment, rennet (CHR Hansen, Chy Max M200–0.5 ml).

FOS of different characteristics were used: (i) inulin provided by Orafti Chile SA and obtained from chicory and (ii) agave native fructans (NF), commercial products of *Agave tequilana* in powder and 72°Brix (Agavetica Monterrey, Mexico). The commercial inulin employed is mainly constituted by linear chains of fructose, with a glucose terminal unit. Short-chain inulin GR was used in concentrations of 3 and 5% (w/w) and long-chain HP at 5% (w/v). Fructans present in Agave, particularly in *Agave tequilana*, have a polymerization degree between 3 and 29 with several β (2–6) bonds in branching fructose molecule.

The amount of fructan added was defined taking into account the conditions set by the Argentine Food Code (AFC), Chap. 17, for foods added with fibers.

For milk skimming, membrane technology was used, more precisely the microfiltration technology. Once skimmed, a physicochemical analysis was carried out, and the process of making the cheeses began.

2.2 Membrane processes for partial skim milk

As mentioned previously, current market demands healthier foods with lower health risks. Thus, it is expected that in a cheese with functional properties, its fat content will be reduced [1]. For the elaboration of the samples of cheeses, raw cow's milk was used, and the fat content was reduced by applying membrane technology.

Membrane technology is a generic term for a series of different and very distinctive separation processes. In essence, the membrane acts as a selective barrier by letting some components pass through it and retaining others depending on the molecular size, with a pressure gradient being the driving force of the process.

The feed (crude milk) was pumped through a frontal polyethylene microfiltration (MF) filter with a pore size of 5–10 μm (Pall Corporation, USA) at room temperature (24 ± 1°C), which is shown in **Figure 1**. Applied transmembrane pressure and recirculation rate were controlled by a valve and by the feed rate, supplied by the variable speed pump from a feed tank. The pressure applied to the membrane was measured with a manometer, and the ermeate was determined by measuring the filtrate volume collected during a certain period of time. This procedure reduced the amount of bacteria and spores and acted as cold pasteurization. The filter was cleaned and sanitized after each experiment and exchanged periodically.

The operation was carried out in three stages, taking a sample from each of them, in order to determine the degree of skimming of the milk in each step for which the fat content was determined.

2.3 Soft cheese manufacture

Partially skimmed milk was divided in different portions of 2.5 L for each batch. One of the portions was reserved to produce a low-fat cheese as a control

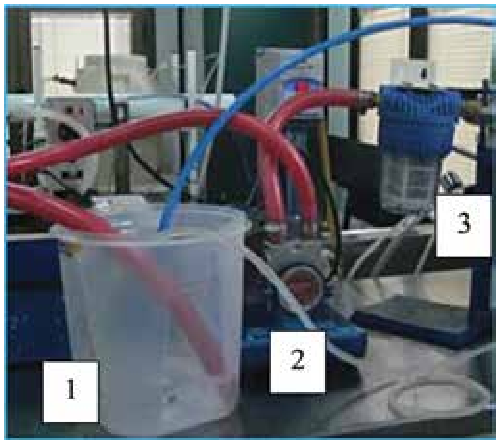

Figure 1.
Frontal MF equipment, used in the skimming of raw milk. (T = 24 ± 1°C): 1: feed tank; 2: pump; 3: MF filter.

(LFCC) sample, and to the rest of the portions, different fructans as inulin GR and HP (at 3 and 5% w/v) and NF [in concentrations of 0.5 and 5% (w/v)] were added. Full-fat control cheeses (FFCC), without fructans, were also produced for comparison.

Different tests were carried out in the stage of FOS aggregation, searching the way in which it would be better retained within the cheese matrix and thus obtaining a food rich in fibers. The alternatives assayed in cheeses elaboration are described as follows:

a. Preparation of samples with added inulin powder

All samples were made in duplicate. The inulin powder previously weighed according to the desired final percentage was added. The addition was done smoothly and slowly by stirring continuously to avoid the formation of lumps. Once the addition of the carbohydrate was done, the elaboration was continued according to the steps described in **Figure 2**.

The samples obtained by this process were labeled as M1 and M2:

- M1: sample with 125 g of inulin powder (5% w/v)
- M2: sample with 37.5 g of inulin powder (1.5% w/v)

b. Preparation of samples with added inulin in gel

Other forms of addition were investigated, such as the addition of carbohydrate prior to the formation of a gel [7]. Inulin shows high-level gelling properties, forming a three-dimensional network of insoluble submicron particles with a large amount of immobilized water, which ensures physical stability.

Regarding the gels made in the laboratory, it was found that the gel with 30% inulin with a heating time of 20 min was the one that exhibited the best consistency. In this way, the cheese samples were developed with incorporated inulin as gel (formed at 30% w/v) in different stages of the elaboration, resulting in samples M3 and M4 (**Figure 2**):

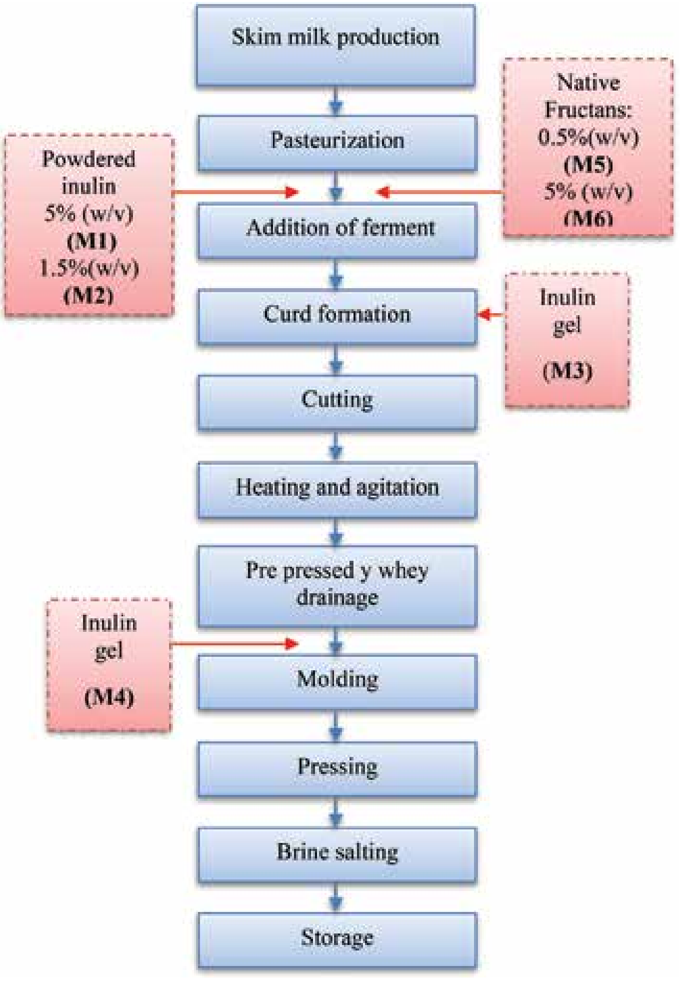

Figure 2.
Flowchart of the soft cheese making process with and without FOS.

- M3: Addition after the incorporation of the rennet and before the curd is formed
- M4: Incorporation of the gel after the syneresis stage, mixing, and molding

c. Preparation of samples with added native agave fructans powder

NF in concentrations of 0.5% and 5% (w/v) was added in powder in the same way as inulin, as is indicated in **Figure 2**.

The samples obtained were identified as:

- M5: addition of FN 0.5%
- M6: addition of FN 5%

Production was carried out in a batch process. Each formulation was replicated at least twice and analyzed independently; also each set of samples was made in the same day. The initial pH was measured (6.89 ± 0.10).

Pasteurization is an operation that is carried out to destroy the pathogenic flora and reduce the banal flora or alteration, so the milk was heated to 65 ± 1°C and kept at this temperature for 30 min. After that time it was quickly cooled using an ice bath. After the addition of fructans in any way, the samples were mixed. Then the temperature was brought to 34.5 ± 2°C, and 1 g of CaCl2 (BDH Chemicals Laboratory Reagents, United Kingdom) was added which contributes to obtain a proper floc. Then the ferment (0.1 g) was added to the batches. When the pH was at 6.5 ± 0.2, the temperature was raised to 37.5 ± 0.5°C, and enzymatic coagulant in powder (0.1 g) was added for coagulation, allowing acting for 40 min. To make sure that the coagulation has come to an end, a knife was placed in the dough, and it was checked that it comes out dry, without curd remains, which indicates that it has already been formed.

Cutting was done 35 ± 5 min later, the grains remained in suspension, and the dough was heated 2°C above the coagulation temperature and was gently stirred (avoiding breaking the curd cubes) and allowed to settle for 10 min. The curd was cut with a curd knife in the shape of 2-cm^3 cubes. The cut curd was allowed to settle for 10 min. Then the temperature was increased by 2 ± 0.5°C while gently mixing so as not to break the curd granules. After that, the samples were poured onto a sieve covered with a cheesecloth for drainage of whey, which was collected in a graduated cylinder. This process facilitates the release of the grain serum from the dough. The cheese curds were put into cylindrical plastic molds of 250 g (Vigna S.A., Argentina) and pressed during 1 h and half of each side (**Figure 3a**). A posterior mold-pressing stage was carried out in an artisanal cheese press (**Figure 3b**) and adjusted to exert pressure on the molds allowing the draining of excess serum. The pressing time was varying between the different batches according to the pH which was decreased to the desired value: 5.4 ± 0.1. Then the samples were placed in saturated brine, calculating the dwell time in the brine according to the weight of the cheeses. The salt regulates the development of microorganisms, enhancing flavors and contributing to the formation of the product's crust. The brine was prepared at a concentration of 21°Baumé (°Be), which is the recommended concentration for soft cheese.

The samples were remained at 6 ± 2°C in a refrigerator and after 24 h were packaged with a plastic film.

2.4 Preadable cream cheese manufacture with added inulin

The addition of native or short-chain inulin (GR) and high-performance (HP) inulin in cream cheeses was studied. These samples were elaborated in the National

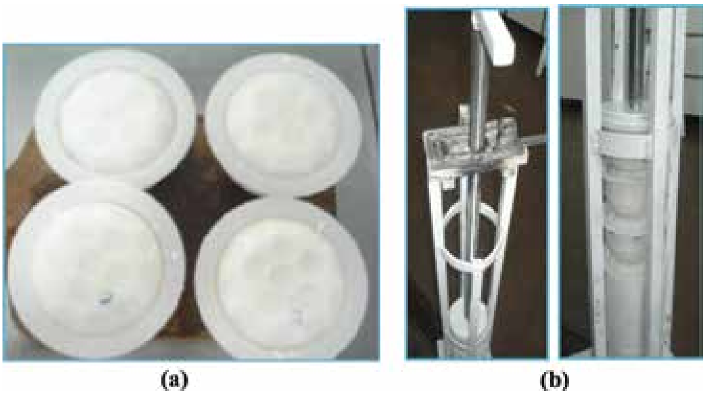

Figure 3.
(a) Plastic molds with cheese samples, (b) cheese press.

Institute of Industrial Technology (INTI of Argentina). **Figure 4** shows the general flow diagram used. In this case the raw material (milk) was provided by Mastellone S.A. (Buenos Aires, Argentine).

The elaboration process was in batch of 20 l of milk. Once the milk was received, a filtering was done to eliminate impurities, and physicochemical determinations were performed.

Pasteurization was carried out at 85 ± 1°C for 30 min. As in the soft cheeses with inulin, after pasteurization, the milk was quickly cooled in an ice bath until reaching

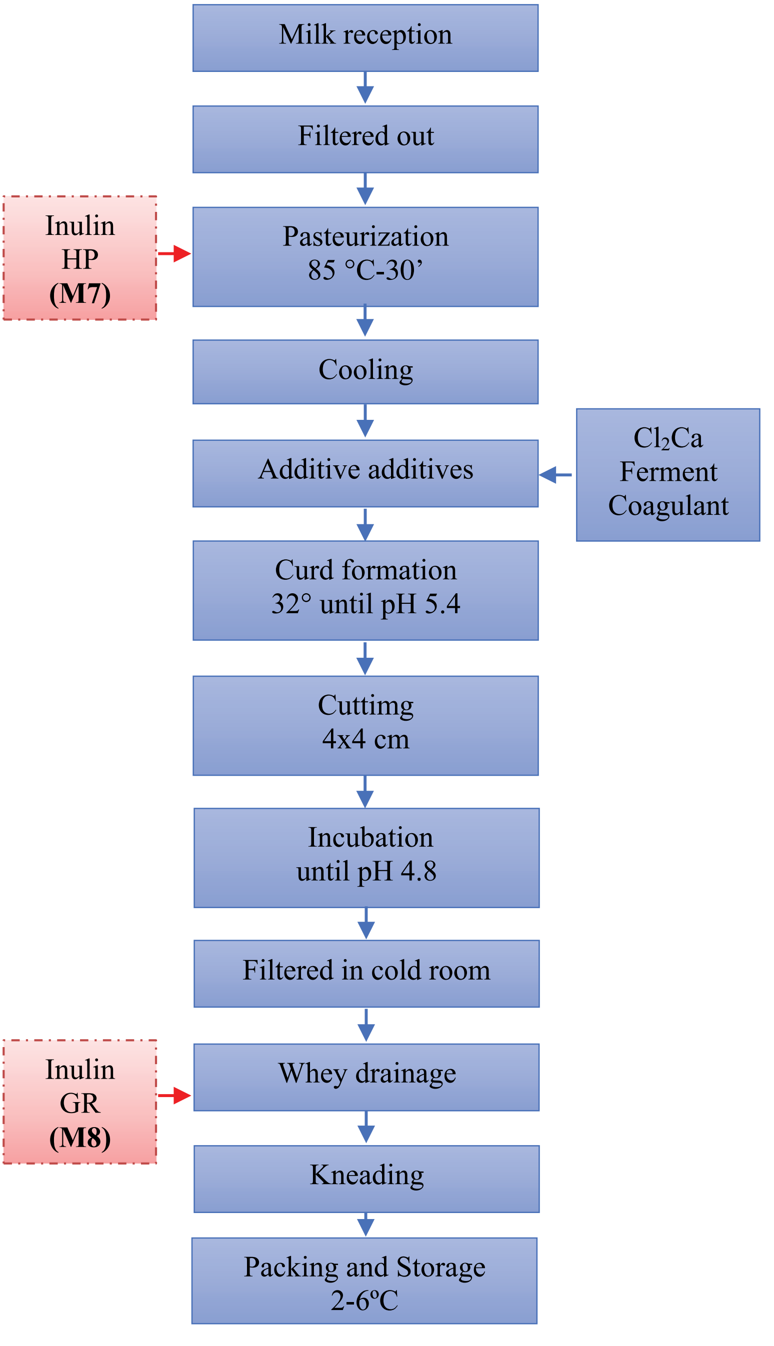

Figure 4.
Flowchart of the cream cheese making process.

Figure 5.
(a) Kneader used in the production of cream cheese (b) and cream cheese.

33 ± 1°C, optimum temperature for the addition of ferment and other additives. In this case, 0.042 g/l of ferment (Sacco M032), 0.13 g/l of CaCl2 (78% purity), and 0.5 ml/l of rennet Chy Max M200 (1/100 dilution) were added, and it was left incubating until it reached pH 5.4. A control sample without inulin was reserved, and the rest incorporated the polysaccharide in different percentages. Short-chain inulin GR was used in concentrations of 3 and 5% (w/w) and long-chain HP at 5% (w/v).

Once the curd was formed, cuts of 4 × 4 cm were made with a lyre and led to take out the whey in a cold chamber until reaching a pH of 4.8 ± 0.1; for this, a cheesecloth was used, like in the production of soft cheeses. It was allowed to run through the night, and then the shaking or texturing stage was reached with a Hobart mixer (USA), shown in **Figure 5a**. The process consisted of 30 s of shaking at speed 1 and then 1.5 min at speed 2, adding inulin during this stage. After shaking, the product was placed in plastic pots (**Figure 5b**) to be taken to the cold room where they were stored for 24 h before making the physicochemical determinations.

Inulin GR (native or short-chain inulin) was added in the texturing or kneading stage, in the form of rain, continuously kneading until a homogenous mixture was obtained. The amounts added were 3% (28.35 g) and 5% (47.25 g), obtaining the samples denominated as M7, M8. HP inulin was added in the pasteurization stage, since it is much more soluble than GR and only in the 5% concentration (47.25 g) reaching to sample M9.

2.5 Analysis

Raw materials and cheeses samples were analyzed in duplicate according to standard replication AOAC [8]. Analyses were performed after 48 h of sample elaboration.

pH was measured using a digital pH-meter (Testo 206-pH 2, Germany).

The protein content was calculated by determination of total nitrogen by the Kjeldahl method using a Digestion Blocks and a semiautomatic Kjeldahl distiller (Selecta, Spain); the conversion factor used to express the results was 6.38 (AOAC 991.22). The fat content was measured by the Rosse-Gottlieb method (AOAC 933.05). Total solids were determined by weight difference, drying in an oven at 70 ± 1°C, during 24 h (AOAC 925.23). The moisture content was determined by gravimetric method (IDF 1982). For ash determination, samples were weighted into porcelain crucibles and incinerated in a muffle furnace (Indef, Argentina) with a temperature programmer to reach 520°C (AOAC 945.46).

The determination of total carbohydrates (lactose plus fructan) was carried out in whey, sub-product of cheese manufacture, using a refractometer (Arcano, China, range 0–32°Brix) in which the soluble compounds are expressed as °Brix. The measurement takes only few seconds [2]. The determination of fructan was made by difference between the amount of total carbohydrates measured and the lactose recorded in the control sample. The fructan value retained in cheeses was obtained by difference between the amount of fructan added and the amount found in the whey.

Also inulin was determined by anion-exchange high-performance liquid chromatography (HPLC) method following water extraction of inulin. HPLC conditions included an Aminex HPX-87C column (Bio-Rad), deionized water at 85°C as the mobile phase with a flow rate of 0.6 ml/min, and a refractive index detector [9].

The surface color was measured by a digital spectrophotometer (Mini Scan EZ, USA) provided with the software. The chromometer was calibrated with the standard white and black color. The results reported are averages of measurements of three slices (five measurements per slice), using CIELAB L^*, a^*, and b^* values. L^* value is the lightness variable from 100 for perfect white to zero for black, while a^* and b^* values are the chromaticity values, +redness/-greenness and + yellowness/-blueness, respectively.

Instrumental texture analysis was determined using the TAXT Stable Microsystems analyzer (London, United Kingdom). A compression test was carried out, using a 5-mm cylindrical test tube and with the following test parameters: pretest speed, 2 mm/seg; test speed, 1 mm/seg; distance, 10 mm; and trigger, 3 g. The assessment was performed in triplicate at 9 ± 2°C.

The sensory evaluation was carried out following different protocols. The samples of soft cheese were tested in a uniformly illuminated room, by 45 members of a semi-trained panel selected from a pool of students and staff members of our department. Prior to assessment, each model cheese sample was divided into various portions and equilibrated at room temperature (22 ± 2°C). A discrimination test was employed in which the evaluator had to establish the difference between a control sample and one or more problem samples, using a scale from 0 (no difference) to 6 (very much different). The samples were coded with three-digit random numbers and were presented in pairs: control vs. sample and control vs. control (as blind witness). The attributes evaluated comparatively were flavor, color, texture, sweetness, and acidity. Panelists were exposed to each sample on an individual Petri plastic dish and were asked to assess a number of specific attributes. Water was provided for rinsing between samples, to clean the palate [10]. The average for all attributes of the sample was calculated, and the differences were analyzed with the analysis of variance using the statistical software GraphPad InStat.

The analysis of samples of cream cheese were carried up by a panel composed of 10 blind and visually impaired people belonging to INTI-Dairy (Buenos Aires), which was selected and trained according to IRAM Norms 20,001/20,002/20,004/20,005 and 20,006.

For the determination of the texture and flavor profiles, the Quantitative Descriptive Analysis (QDA) technique contemplated in IRAM Standards 20,012 and 20,013 was used. These standards contemplate the analysis of the texture profile and procedures indicated in the "Guide D'Evaluation Sensorielle de la Texture des fromages a pâte dure ou semidure," 1994, of the European Union.

From the texture profile, the following descriptors were determined: (a) adherence, work that must be done with the tongue to detach a product stuck on the palate and the teeth; (b) solubility, a sensation that is highlighted when the sample melts very quickly in the saliva after chewing it four times with the molars; (c) humidity impression, perception of the moisture content of a food by means of tactile receptors in the mouth; (d) creaminess, a combination of properties such as viscosity, particle size, and lubrication; and (e) microstructure, related with geometric properties, particle size, shape, and arrangement, of the particles.

In the analysis of the flavor profile of cream cheeses, the following descriptors were evaluated, salty taste, sweet taste, bitter taste acid, and global persistence, relative to the response to a stimulus associated with a measurable period of time (IRAM 20001). Increasing continuous scales from 1 to 7 were used to express the intensity perceived in each descriptor. The panelists worked individually in booths analyzing in triplicate a number of two samples per session. Before performing the analysis, the samples were stabilized for 1 h at 9 ± 2°C and were presented inside sterilized glass vessels.

Data from the cheesemaking trials was statistically analyzed using the computer program "GraphPadInStat." The obtained data were statistically evaluated by the Tukey-Kramer multiple comparison test in the cases where two or more comparisons were considered. Otherwise, the t-test was used, assuming that a $p < 0.05$ was statistically significant [11].

3. Characterization of the skimming of raw milk by microfiltration

The raw material analysis indicated that it has a pH of 6.89 ± 0.02 and the following composition in w/100 g, 3.50 ± 0.08 of proteins, 2.00 ± 0.18 of fat, 50.00 ± 0.30 of saccharides, and 0.70 ± 0.05 of ash.

The results obtained showed that a fat content reduction of 76% (w/v) was achieved during the first stage, confirming that milk skimming by microfiltration was effective to obtain samples reduced in fat. The conventional operation to perform the separation of fat globules from milk is centrifugation. The decantation and spontaneous coalescence of the fat globules on the surface of the milk is slow; for this reason it is necessary to accelerate it by means of centrifugal separators. However, this technique presents difficulties during the separation of the fatty phase and requires the application of a high mechanical force. In the case of MF, fats are retained in the membrane. Thus, filtration technology is an effective way to achieve superior quality and safety, without compromising the fundamental sensory characteristics of the product. Also elimination of unwanted ingredients, such as microorganisms or sediments, which have a negative effect on quality, can be done, improving the texture of the final product and increasing its duration. On the other hand, it can shorten the stages of production and increase the yield, allowing a high degree of selectivity, and its energy costs are reduced. Similar results were reported in Refs. [12, 13].

4. Physicochemical and sensory characterization of cream cheeses with and without FOS

The results of the physicochemical characterization of the products are shown in **Table 1**. As expected, the highest change was in the fat cheese composition, between the full-fat cheese control and the rest of samples ($p < 0.05$). The codex general standard for cheese [14] determined that the FFCC obtained corresponds to a medium-fat cheese (25–45% w/w fat on dry basis) and the rest of the samples developed, to a low-fat cheese (10–25% w/w fat on dry basis). As the fat content

Sample	Moisture (%w/w)	Proteins (%w/w)	Fat (%w/w)	Ash (%w/w)	Carbohydrates (%w/w)
FFCC	46.05 ± 2.5	23.06 ± 1.5	24.07 ± 3.45	3.8 ± 0.32	3.02 ± 1.05
LFCC	48.95 ± 4.35	26.18 ± 1.01	15.83 ± 1.17	4.05 ± 0.35	4.99 ± 1.15
M1-inuline (5%)	49.09 ± 1.35	25.52 ± 1.02	13.98 ± 0.40	3.89 ± 0.44	7.52 ± 0.50
M2-inuline (1.5%)	49.01 ± 1.46	26.37 ± 2.17	14.16 ± 2.69	4.27 ± 0.47	6.144 ± 2.46
M5-agave fructan (0.5%)	48.14 ± 1.67	28.45 ± 0.76	12.98 ± 0.55	4.05 ± 0.1 9	6.38 ± 1.92
M6-agave fructan (5%)	47.46 ± 1.90	30.58 0.54	12.52 ± 0.14	3.67 ± 0.13	5.77 ± 0.72

Table 1.
Physicochemical characterization of cream cheeses with and without FOS, at different concentrations (means ± SD).

of cheese is lowered, moisture content increases, and protein plays a greater role in texture development [15]. Thus, according to the Argentinean legislation [16], the samples correspond to cheeses of high moisture (46–54.9% w/w of moisture content) and reduced in fat (10.0–24.9% w/w of fat content).

The samples M3 and M4, with inulin added as gel in different steps of cheesemaking (**Figure 2**), have similar composition with that of M2 samples.

The samples with fructans showed an appropriate protein retention, higher than other results reported in Ref. [17], being the formulations with native fructans which retained the higher amount of fructans (M5 and M6), where a higher concentration of the NF affects greater protein retention ($p < 0.05$). This difference is attributed to the fact that, as mentioned, these fructans have a branched structure that can contribute better to forming a protein-saccharide network. The role of the agave fructans in the cheese matrix is significant, taking into account that they are considered as soluble fiber from natural and abundant sources, categorized as prebiotics. Thus, they become a valuable alternative as a functional ingredient in order to obtain functional foods.

Regarding the carbohydrate values, the amount of specific FOS retained by the matrix was determined by HPLC. The results are presented in **Table 2**.

The results showed that the amount of inulin retained in M1 and M2 was very low probably due to its high solubility. The inulin incorporated as a gel at different times of the elaboration stage showed better results in terms of retention; however, it did not meet the expectations for the formulation of a functional type of cheese. Greater retention was achieved in the case of native agave fructan, probably as mentioned by the type of structure and lower solubility that allowed obtaining a microstructure with the proteins very similar to that of the whole control cheese sample, as was reported by SEM studies by [2].

The color determination in the samples is presented in **Table 3**.

Control samples and cheeses with fructans showed high L^* value (> 80) which indicates the degree of luminosity; this parameter has a greater impact on the perceived appearance of the product. The values obtained were similar to other soft cheeses reported in the literature [18]. The values of a^* were positive close to zero without presenting significant differences between the samples ($p > 0.05$). The positive value of b^* indicated the degree of yellow hue. These values are adequate considering that they are low-fat cheeses and the elimination of fat imparts a translucent appearance. In effect, the colorimetric parameters obtained were in the order

Sample	Inulin (%w/w)
FFCC	—
LFCC	—
M1-inuline (5%)	1.04 ± 0.11
M2-inuline (1.5%)	0.65 ± 0.09
M3-inuline gel	1.80 ± 0.11
M4-inuline gel	1.30 ± 0.17
M5-agave fructan (0.5%)	0.90 ± 0.11
M6-agave fructan (5%)	4.12 ± 0.15

Table 2.
Determination of FOS in the samples of cheese (means ± SD).

Sample	L	a	b
FFCC	85.30 ± 2.14	1.20 ± 0.11	18.37 ± 2.43
LFCC	86.11 ± 3.41	0.19 ± 0.16	14.89 ± 2.57
M1-inuline (5%)	84.58 ± 2.12	0.57 ± 1.12	17.32 ± 0.6 5
M2-inuline (1.5%)	82.26 ± 2.14	0.27 ± 0.15	16.90 ± 1.14
FN 0.5	81.50 ± 1.01	0.48 ± 0.18	16.32 ± 1.13
FN 5	89.60 ± 1.14	0.34 ± 0.09	16.66 ± 0.45

Table 3.
Surface cheese-like product color (means ± SD).

of those reported for low-fat cheeses without coloring [19]. The results verified that the presence of fructans did not significantly affect the color of the samples with respect to the control cheese.

The sensorial analysis indicates a good acceptation of all the products according to the concentration range employed and did not present significant difference with regard to the control samples, indicating that the FOS did not affect these parameters. Even though it would be difficult to mimic entirely a full-fat cheese after fat has been removed, the presence of fructans in reduced fat formulations suggests an acceptable likeness in relation to structure and general characteristics of the full-fat control cheese. This fact constitutes a technological challenge.

5. Characterization of soft cheeses with added inulin

5.1 Physicochemical composition

Table 4 shows the physicochemical composition of the soft cheese samples carried out by the process described in **Figure 4**, with inulin GR and HP added at 3% and 5% (w/v), which were also compared with a control samples without the polysaccharide (LFCC).

Each of these determinations was carried out in duplicate following the methodologies described for cream cheeses.

The results show that the cheeses are of high-moisture, higher than 70% w/w and low in fat minor of 11% w/w. In the case of carbohydrates, it is demonstrated that the addition of inulin was effectively retained in the cheese matrix, in

Sample	Moisture (%w/w)	Fat (%w/w)	Protein (%w/w)	Carbohydrates (%w/w)	Ash (%w/w)
LFCC	74.06 ± 0.88	10.90 ± 0.14	10.79 ± 1.28	3.61 ± 0.57	0.65 ± 0.02
GR3	73.54 ± 3.31	10.23 ± 1.91	10.21 ± 1.75	6.52 ± 0.46	0.61 ± 0.03
GR5	73.56 ± 2.59	9.50 ± 1.41	8.57 ± 1.58	7.76 ± 0.42	0.63 ± 0.00
HP5	74.48 ± 1.20	10.80 ± 1.33	9.48 ± 0.99	5.36 ± 0.40	0.68 ± 0.00

Table 4.
Physicochemical characterization of soft cheeses with and without FOS, at different concentrations (means ± SD).

Sample	Inulin (%w/w)*
C	0 ± 0.00
GR3	2.91 ± 0.13
GR5	2.84 ± 0.19
HP	0 ± 0.00
HP (in whey)	5.29 ± 0.01

**Detection limit: 0.01 g/100 g*

Table 5.
Inulin determination in soft cheese by HPLC (mean ± SD).

particular for the GR inulin since the increments found correspond to the quantities actually added. The determination by HPLC corroborated this result as it is shown in **Table 5**.

Cream cheese samples with inulin GR showed a retention of almost 100% of the added inulin. However, the HP inulin added to the sample was completely lost in the serum corresponding to that sample.

The AFC (Chap. XVII, Art. 1386) indicates that for a food to be considered with added fiber, it must have at least 3 g/100 g in the case of solid foods and 1 g/100 ml of liquid foods. In the USA, the recommended daily consumption is 1–4 g/day, while in Europe a consumption of 3–11 g/day is suggested. Taking into account the results, we can say that the inulin content is high with respect to the recommended amounts and that the cheeses were effectively enriched in fibers.

5.2 Sensory evaluation of soft cheese with and without inulin

The results obtained in the sensory evaluation carried out by the trained panel of INTI-Dairy are presented in **Table 6**.

In this analysis, a sample of commercial spreadable cheese (CC), with similar characteristics, without fructans was added. The results of the sensory analysis indicated significant differences in the sweet flavor attribute and in the texture attribute creaminess and microstructure. The rest of the parameters analyzed did not show significant differences. Regarding the sweet taste, the difference found between the control sample (LFCC) and the sample with 5% inulin GR (GR5) may be due to the sweetening power of inulin, which, although much lower than that of sucrose, is considered a natural sweetener and when increasing the concentration it seems that it begins to be noticed. The differences found in the creaminess and the microstructure may be due to the kneading conditions, as it is known that this mechanical treatment significantly influences the expression of the aforementioned parameters.

Sample	Sweet	Salad	Acid	Bitter	Persistence	Adherence	Creaminess	Moisture Impression	Microstructure	Solubility
LFCC	$2.06^{a} \pm 0.78$	2.38 ± 0.99	4.19 ± 0.75	2.63 ± 0.86	3.75 ± 0.83	3.13 ± 1.83	$5.13^{a} \pm 1.36$	3.25 ± 1.48	$2.06^{a} \pm 1.18$	5.63 ± 0.92
CC	$2.50^{a,b} \pm 0.93$	2.63 ± 1.11	4.56 ± 1.11	3.44 ± 0.46	$4.00 \pm 1,41$	3.75 ± 2.22	$3.81^{a,b} \pm 0.86$	3.56 ± 1.26	$2.75^{a,c} \pm 1.09$	5.50 ± 1.31
GR3	$2.50^{a,b} \pm 1.31$	2.06 ± 0.95	4.00 ± 0.87	3.31 ± 0.66	3.69 ± 1.48	1.94 ± 1.13	$3.06^{b} \pm 1.33$	4.13 ± 1.62	$5.25^{b} \pm 0.97$	5.25 ± 1.58
GR5	$3.63^{b} \pm 1.22$	2.19 ± 0.61	4.00 ± 0.87	2.56 ± 0.68	3.25 ± 0.97	3.06 ± 2.01	$5.00^{a} \pm 1.22$	3.81 ± 1.27	$1.94^{a} \pm 0.81$	5.38 ± 1.19
HP5	$2.25^{a,b} \pm 0.86$	2.5 ± 0.85	4.38 ± 1.24	3.13 ± 0.91	3.63 ± 1.22	3.29 ± 1.78	$4.94^{a} \pm 1.21$	3.60 ± 1.31	$3.69^{c} \pm 0.94$	5.19 ± 1.22

The supra-indices a, b, and c indicate significant differences between the results in the same column ($p < 0.05$).

Table 6.
Sensory analysis results of soft cheeses with inulin GR and HP (mean ± SD).

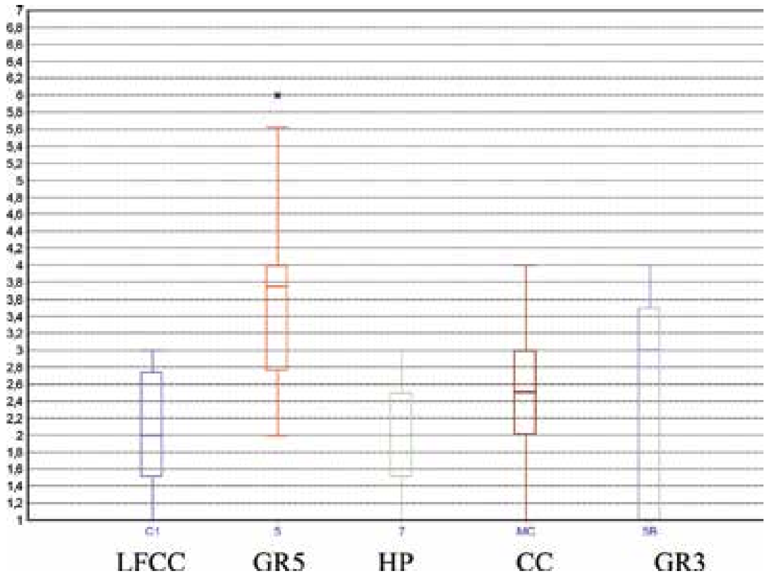

Figure 6.
Box plots for the sweet taste attribute of the spreadable soft cheeses.

Sample	Adhesion (g/sec)	F_{max} (g)	Elasticity	$Work_{max}$ (g/sec)
LFCC	88.28 ± 6.15	20.41 ± 1.09	9.96 ± 0.06	151.24 ± 10.31
GR3	86.21 ± 3.61	15.77 ± 0.88	9.96 ± 0.02	114.48 ± 4.70
HP5	83.78 ± ±8.74	16.57 ± 0.50	9.97 ± 0.03	118.95 ± 7.35

Table 7.
Instrumental texture of soft cheeses with and without inulin (mean ± SD).

Additionally, a statistical analysis of boxes and mustache or box plots was made for the different attributes. **Figure 6** shows the graph obtained for the sweet taste, where the significant difference between the control sample and the GR5 inulin sample can be seen more clearly.

The data obtained for instrumental analysis texture is presented in **Table 7**. This analysis was performed in triplicate.

Significant differences were found in the maximum work values between the cheese samples with inulin and the control sample. In this sense, inulin in general modifies the hardness of foods, increasing this parameter according to the food formulation in which it is applied, as was previously shown [20]. However, in the hardness results of the samples analyzed, they show a decrease in this parameter.

This may be due to the fact that the presence of serum proteins disturbs the fine structure that is formed between the inulin crystals by Van der Waals bonds, allowing the gel formation, generating a decrease in hardness [7].

6. Conclusions

In this chapter, different experiments of incorporation of fructans in cheese-making matrices were carried out, trying to obtain a reduced fat cheese additive with compounds that behave like prebiotics and act as dietary fiber. This search led to the testing the incorporation of inulins of different origin and degree of polymerization to two types of cheese: soft and cream cheese.

From the wide experimentation carried out, it was possible to conclude that in the development of soft cheeses with inulin, in all cases the samples had a reduced fat content and high humidity. The texture and the micrographs showed adequate similarity with the control cheeses without the addition of inulin. However, the inulin retention was insufficient to have a food with the desired functional characteristics.

In the case of cheeses with agave fructans, a greater retention of the oligosaccharide was shown, given that it has a more branched structure that probably contributes to a better retention through the protein matrix. On the other hand, the determinations of color, texture, and sensory analysis did not show significant differences by the addition of the fructan. This conclusion is important since it opens the possibility of diversifying the uses of agave, a plant of rapid and widespread growth in America.

Finally, the experiments made with creamy cheeses, type spreads indicated that the composition of these samples responded to a high content of moisture and low-fat content, where proteins and carbohydrates adequately compensated the texture of the samples. But in this case, it was determined that GR inulin (native or short-chain inulin) was retained 100% in the cheese matrix, obtaining a product with the desired functional characteristics.

The sensory and texture profiles additionally showed that they are cheeses similar to the control samples with adequate parameters that make the product obtain a spreadable cheese with functional characteristics according to the needs of the market.

Even though it would be difficult to mimic entirely a full-fat cheese after fat has been weakened, the presence of FOS in reduced fat formulations suggests an acceptable likeness in relation to structure and general characteristics of the full-fat control cheese. This fact constitutes a technological challenge. The role of fructans in the cheese matrix is significant, taking into account that they are considered as soluble fiber from natural and abundant sources, categorized as prebiotics. Thus, they become a valuable alternative as a functional ingredient in order to obtain functional foods.

Future work should be carried out to confirm these findings and thus optimize the addition of fructans in different formulations of dairy products.

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Conflict of interest

There is no conflict of interest in the work presented.

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Acronyms

AFC	Argentine Food Code
AOAC	Association of Official Agricultural Chemists
FFCC	full-fat control cheese
FOS	fructooligosaccharide
GR	native or short-chain inulin
HP	high-performance inulin
HPLC	high-performance liquid chromatography
IRAM	Instituto Argentino de Normalización y Certificación
LFCC	low-fat control cheese
MF	microfiltration
NF	native fructans

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References

[1] Juan B, Zamora A, Quintana F, Guamis B, Trujilla AJ. Effect of inulin addition on the sensorial properties of reduced-fat fresh cheese. International Journal of Dairy Technology. 2013;**66**:478-483. DOI: 10.1111/1471-0307.12057

[2] Palatnik DR, Aldrete Herrera P, Rinaldoni AN, Ortiz Basurto RI, Campderrós ME. Development of reduced fat cheeses with the incorporation of agave fructans. International Journal of Dairy Technology. 2016;**69**:1-8. DOI: 10.1111/1471-0307.12334

[3] Sáyago-Ayerdi SG, Mateos R, Ortiz-Basurto RI, Largo C, Serrano J, Granado-Serrano AB, et al. Effects of consuming diets containing Agave tequilana dietary fibre and jamaica calyces on body weight gain and redox status in hypercholesterolemic rats. Food Chemistry. 2014;**148**:54-59. DOI: 10.1016/j.foodchem.2013.10.004

[4] Wang Y. Prebiotics: Present and future in food science and technology. Food Research International. 2009;**42**: 8-12. DOI: 10.1016/j.foodres.2008. 09.001

[5] Bosscher D, Van Loo J, Franck A. Inulin and oligofructose as functional ingredients to improve bone mineralization. International Dairy Journal. 2006;**16**:1092-1097. DOI: 10.1016/j.idairyj.2005.10.028

[6] Cassano A, Rastogi NK, Basile A. Membrane technologies for water treatment and reuse in the food and beverage industries. In: Basile A, Cassano A, Rastogi NK, editors. Advances in Membrane Tech. for Water Treatment. Cambridge, UK: Woodhead Publishing Series in Energy; 2015. pp. 551-580. DOI: 10.1016/ C2013-0-16469-0

[7] Glibowski P. Rheological properties and structure of inulin-whey protein gels. International Dairy Journal. 2009;**19**:443-449. DOI: 10.1016/j. idairyj.2009.03.011

[8] Horwitz W, Latimer G, editors. Official Methods of Analysis of AOAC International—18th Edition. In: Revision 18th AOAC International. USA: Annual Book of ASTM Standards; 2010

[9] Zuleta A, Sambucetti ME. Inulin determination for food labeling. Journal of Agricultural and Food Chemistry. 2001;**49**:4570-4572. DOI: 10.1021/ jf010505o

[10] Meilgaard MC, Arbor A, Carr T, Civille GV. Sensory Evaluation Techniques. 4th ed. Boca Raton, Fla, London: CRC, Taylor & Francis; 2006. p. 488

[11] SAS. USER GUIDE: Statistic. Version. Cary, NC, USA: SAS Inst. Inc; 1989

[12] Rinaldoni AN, Campderrós ME, Menéndez C, Pérez Padilla A. Fractionation of skim-milk by an integrated membrane process for yogurt elaboration and lactose recuperation. International Journal of Food Engineering. 2009;**5**:1-17. DOI: 10.2202 /1556-3758.1531

[13] Mercier-Bouchard D, Benoit S, Doyen A, Britten M, Pouliot Y. Process efficiency of casein separation from milk using polymeric spiral-wound microfiltration membranes. Journal of Dairy Science. 2017;**100**:8838-8848. DOI: 10.3168/jds.2017-13015

[14] Kosikowski FV, Mistry VV. Cheese and fermented milk foods. In: Origins and Principles. Vol. 1. 3rd ed. Westport, USA: FV Kosikowski LLC; 1997. p. 728

[15] Mistry VV. Low fat cheese technology. International Dairy Journal. 2001;**11**:413-422. PII: S 0958-6946(01)00077-2

[16] Argentian Food Code, Administración Nacional de Alimentos, Medicamentos y Tecnología Médica Capítulo VIII (Alimentos Lácteos). Available form: http://www.anmat.gov.ar/alimentos/codigo/CAPITULO_VIII.pdf

[17] Salvatore E, Pes M, Mazzarello V, Pirisi A. Replacement of fat with long-chain inulin in a fresh cheese made from caprine milk. International Dairy Journal. 2014;**34**:1-5. DOI: 10.1016/j.idairyj.2013.07.007

[18] Juric M, Bertelsen G, Mortensen G, Petersen MA. Light induced colour and aroma changes in sliced, modified atmosphere packaged semi-hard cheeses. International Dairy Journal. 2003;**13**:239-249. PII: S 0958-6946 (02)00156-5

[19] Wadhwani R, McMahon DJ. Color of low-fat cheese influences flavor perception and consumer liking. Journal of Dairy Science. 2012;**95**:2336-2346. DOI: 10.3168/jds.2011-5142

[20] Rodríguez Furlán LT, Baracco Y, Lecot J, Zaritzky N, Campderrós M. Influence of hydrogenated oil as cocoa butter replacers in the development of sugar-free compound chocolates: Use of inulin as stabilizing agent. Food Chemistry. 2017;**217**:637-647. DOI: 10.1016/j.foodchem.2016.09.054

Chapter 7

Probiotic Characteristics and Health Benefits of the Yogurt Bacterium *Lactobacillus delbrueckii* sp. *bulgaricus*

Ayowole Oyeniran, Rabin Gyawali, Sulaiman O. Aljaloud, Albert Krastanov and Salam A. Ibrahim

Abstract

Yogurt is a good source of several micronutrients and has played an important role in human nutrition. Consumption of yogurt has been shown to promote health benefits due to the presence of live bacteria. A number of human studies have demonstrated that yogurt contains viable bacteria, and especially *L. bulgaricus*, improve the health of the host and thus qualifies as a bona fide probiotic in its own right. In this chapter, we review the literature covering attributes of the yogurt bacterium *L. bulgaricus* that confirm its probiotic bacterial characteristics.

Keywords: yogurt, *L. bulgaricus*, probiotic, health benefits

1. Introduction

Yogurt, defined as the product of milk fermentation by *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus*, has a long history of beneficial impact on the well-being of humans. As starter cultures for yogurt production, lactic acid bacteria (LAB) display symbiotic relations during their growth in milk medium. To meet the National Yogurt Association's criteria for "live and active culture yogurt," the final yogurt product must contain live LAB in amounts $\geq 10^8$ CFU/g at the time of manufacture, and the cultures must remain active up to the end of the stated shelf life. These live cultures are also considered to be probiotics because the cultures provide health benefits to the host when consumed in sufficient amounts [1, 2].

Elie Metchnikoff can be credited as the progenitor of what has now become a highly profitable industry, probiotics. He theorized that health could be improved and senility delayed by colonizing the gut with the host-friendly bacteria found in yogurt. In a market report published by Allied Market Research, the global probiotics market is expected to garner $57.4 billion by 2022, registering a compound annual growth rate (CAGR) of 7.7% during the period 2016–2022. Asia-Pacific was the dominant probiotics market and is expected to be the leading contributor in global revenue due to its high level of adoption of probiotic based food and beverages.

The definition of probiotics has evolved over the years due to some gray areas regarding the characteristics of a typical probiotic. The internationally endorsed definition of probiotics is "live microorganisms that, when administered in adequate amounts, confer a health benefit on the host" [3]. Modulation of the host's immune system and promotion of host defense are the most commonly supported benefits of probiotics consumption [3]. Most probiotics are lactic acid bacteria *Lactobacillus* sp., *Bifidobacterium* sp., and *Enterococcus* sp.; *Escherichia coli* strain Nissle 1917; the yeast *Saccharomyces boulardii*; some enterococci (*Enterococcus faecium* SF68); *Bacillus* sp., and *Clostridium butyricum* [4, 5, 54].

2. Origin of *Lactobacillus bulgaricus*

Elie Metchnikoff was a Russian biologist and Nobel Prize laureate who attributed the longevity of Bulgarians who were regular consumers of yogurt to the lactobacilli bacteria of yogurt. Metchnikoff's claims attracted wide attention to yogurt at that time. However, it was the Bulgarian graduate student Grigoroff [6] who first isolated and characterized this lactobacilli bacteria from the starter used in producing Kiselo Mlyako (Bulgarian Yogurt). Grigoroff named the bacterium '*Bacillus A*' or what is now recognized as *Lactobacillus bulgaricus* according to the Bergey's classification of bacteria. The origin and natural habitat of commercial *L. bulgaricus* strains may not have a definite answer despite its strong Bulgarian ties as countries like China, Mongolia, Russia, and Turkey also enjoy a long history of naturally fermented dairy products. A study by Song et al. [7] highlighted the uniqueness of *L bulgaricus* strains isolated from traditionally fermented milk products from some of the aforementioned countries.

Moreover, it appears *L. bulgaricus* is on a continuing evolutionary journey as it has adapted itself from a plant source to milk-rich environment [8]. Michaylova et al. [9] have been able to isolate and characterize *L. bulgaricus* from certain plant species (*Cornus mas*) obtained from four regions in Bulgaria. Yılmaz et al. [10] isolated *L. bulgaricus* from raw milk samples collected from different parts of Turkey, while *L. bulgaricus* was one of the isolates from raw milk samples obtained from four races of Algerian goats [11]. A study by Song et al. [7] illustrates the diversity of *L. bulgaricus* and the fact that it might not be an exclusive preserve of Bulgaria.

2.1 *L. bulgaricus* as a probiotic

Elie Metchnikoff is regarded in some quarters as the grandfather of probiotics because of the profound observation he made at the beginning of the twentieth century, a time when the function of the gut flora was completely alien and unknown. Elie Metchnikoff realized that there was a link between regular consumption of lactic acid bacteria in fermented milk products to longevity and enhanced health in a certain group of Bulgarian people. He attributed this beneficial effect to the colonization and implantation of the Bulgarian bacillus which is now characterized as *L. bulgaricus.* Elie Metchnikoff believed that aging and diseases were caused by putrefaction of protein in the bowel by intestinal bacteria and that LAB were capable of inhibiting the growth of these putrefactive bacteria. He was so committed to the fact that fermented products could beneficially alter the microflora of the gut and prolong life that he drank sour milk fermented by lactic acid bacteria every day until his death [12–14].

L. bulgaricus has all the attributes of standard probiotic bacteria. It is crucial for probiotic strains to be able to colonize the intestine and survive passage through the upper gastrointestinal tract (GI) in order confer health benefits [15].

However, there are doubts about the adhesion and survival of *L. bulgaricus* after passage through the human gut. For example, *L. bulgaricus* are not native flora of mammals plus they do not have enough bile salt hydrolase genes and cannot synthesize mucin-binding proteins, all of which are important for survival in the GI [8]. However, regular consumption of yogurt fermented by *L. bulgaricus* may facilitate the colonization of these bacteria in the gut. Elli et al. [16] investigated the recovery of viable *L. delbrueckii* subsp. *bulgaricus* and *S. thermophilus* from the fecal samples of 20 healthy volunteers who were fed commercial yogurt for 1 week and found these bacteria present in the samples, suggesting that the bacteria, can survive transit in the gastrointestinal tract. Similarly, Mater et al. [17] had earlier established the survival of *L. bulgaricus* and *Streptococcus thermophilus* after passage through the gastrointestinal tract. A total of 37 out of 39 stool samples retrieved from 13 healthy subjects over a 12-day period yogurt intake contained viable *L. bulgaricus*. An encapsulated mixture of *L. bulgaricus* and *S. thermophilus* in chitosan and sodium alginate also survived in a simulated gastrointestinal tract [18].

In a study involving 61 elderly volunteers who were randomly assigned to receive either placebo or probiotics, Moro-Garcia et al. [19] evaluated the immunomodulatory capacity of *Lactobacillus delbrueckii* subsp. *bulgaricus* 848, strain isolated from a region of Bulgaria (Stara Planina) known for the longevity of its population [20]. A positive effect on the immune system was recorded in that study. Blood samples were taken at the beginning of the study and again after 3 and 6 months for the researcher to characterize the cell subpopulation, measured cytokines, quantified T cell receptor excision circles (TREC), and determined human β-defensin-2 (hBD-2) concentrations and human cytomegalovirus (CMV). The group that received *Lactobacillus delbrueckii* subsp. *bulgaricus* 848 had an increase in the percentage of NK cells, an improvement in the parameters defining the immune risk profile (IRP), and an increase in T cell subsets that are less differentiated. There was also a reduced concentration of pro-inflammatory cytokine interleukin-8 but an increase in the antimicrobial peptide hBD-2. In a similar study comparing the consumption of yogurt with milk in elderly subjects, yogurt fermented with *Lactobacillus delbrueckii* ssp. *bulgaricus* OLL1073R-1, a polysaccharide-producing lactic acid bacterial strain, was more effective in reducing the risk of catching the common cold. *Lactobacillus delbrueckii* ssp. *bulgaricus* OLL1073R-1 has been proven to have better effects on the immune system than other lactic acid bacteria. For example, the cell body and the immunostimulatory polysaccharides of these bacteria were identified responsible for the activation of biological defense mechanisms against pathogens such as viruses [21]. A recent study by Yamamoto et al. [22] corroborated the immunomodulatory effect of *Lactobacillus delbrueckii* ssp. *bulgaricus* OLL1073R-1. Thirty-seven elderly persons residing in a single nursing had their immunoglobulin A (IgA) levels increased after ingesting 112 g of the yogurt every morning for 12 weeks. IgA plays a critical role in the defense of mucous membranes against foreign antigens and pathogens, directly neutralizing the infectivity of pathogens and their toxins.

Today's health-conscious consumers are increasingly aware of food content which is a driving force in the market for organic foods. For example, some consumers are motivated to take extra steps to avoid foods that contain chemical preservatives. Despite the fact that chemical preservatives are generally regarded as safe, the long-term side effects are unknown. Focus is thus being shifted to bio-preservation as an alternative. The use of LAB strains as a probiotic and bioprotective culture in fermented products has been widely studied. LAB have a major potential for use in biopreservation to extend shelf life and enhance the safety of foods [23]. For example, metabolites and antimicrobial products obtained from LAB have inhibitory effect against spoilage microorganisms. Most importantly, LAB produce organic acid such as lactic acid that reduced the pH of the food, thereby inhibiting the growth of other microflora [24, 25]. In the case of yogurt, drop in pH alters the yogurt environment resulting in an unfavorable medium for the development of some pathogens and spoilage microorganisms [26]. For example, strains of *Lactobacillus delbrueckii* ssp. *bulgaricus* and *Streptococcus thermophilus* isolated from Turkish homemade yogurt had inhibitory effects on *Escherichia coli* and *Listeria monocytogenes* [27].

The use of antimicrobial peptides such as bacteriocins that are produced by LAB will help to significantly minimize the use of chemical preservatives and could thus be used in hurdle technology to produce a more naturally preserved food. LAB produce bacteriocins, bioactive peptides or proteins, and bacteriocin-like inhibitory substances that are antimicrobial compounds that possess bacteriocin capacities requisites but have not been characterized for their amino acid sequence [24, 25]. Some *L. bulgaricus* strains which were isolated from yogurts had an antibacterial effect on *Vibrio cholerae* and *E. coli* due to significant bacteriocin production [28]. A study by Boyanova et al. [29] suggested that the bacteriocin-like inhibitory effects of GLB strains of *L. bulgaricus* could be valuable in the control of *Helicobacter pylori* infections. Clinical benefits were also reported in Thailand, where the addition of *L. delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* either before or before and after a 1-week tailored triple therapy regimen significantly improved eradication rates in *H. pylori infection* treatment [30].

Another area of diet concern in which probiotics come into play is the issue of lead (Pb) poisoning. Food and supplements or methods of food preparation may be a source of lead exposure that can have devastating effects on human health, and it remains a public health concern. *L. bulgaricus* KLDS1.0207 that has been isolated from traditional dairy products in Sinkiang Province, China has been evaluated for its protective effects against acute lead toxicity in mice. The high Pb-binding ability and high resistance to Pb in *L. bulgaricus* KLDS1.0207 offered protective effects from acute Pb toxicity in mice. The results in vivo demonstrated that this particular strain of *L. bulgaricus* can relieve renal pathological damage, reduce mortality rates, and enhance the antioxidant index in the liver and kidney making it a potential probiotic against lead toxicity [31, 32].

Another claimed health benefit linked to probiotics is an improvement in lactose metabolism ([33, 34]). It is widely agreed that fermented milk products such as yogurt can help with lactose digestion in lactose malabsorbers and therefore can be well tolerated by most lactose-intolerant subjects. Yogurt preparation using the traditional *S. thermophilus* and *L. delbrueckii* ssp. *bulgaricus* are even more effective due to their higher β-galactosidase activity. Lactose intolerance is a β-galactosidase deficiency resulting in the inability to digest lactose into the monosaccharides glucose and galactose. People with lactose intolerance develop diarrhea, abdominal discomfort, and flatulence after consumption of milk or milk products. Numerous studies have shown better lactose digestion and consequently less hydrogen exhalation in lactose malabsorbers who consumed yogurt with live cultures rather than with milk or pasteurized yogurt [35, 36].

All of these documented benefits and characteristics of probiotics, in general, provide an equally compelling argument for the effectiveness of *L. bulgaricus* as a probiotic. Yogurt remains one of the most important vehicles for the delivery of probiotic bacteria.

Table 1 lists *L. bulgaricus* strains that are beneficial for a range of health-related issues.

L. bulgaricus strain	Probiotic activity	References
RTF	Antibacterial activity against *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas fragi*, *Micrococcus flavus*	[37]
7994	Inhibitory effect on *Achromobacter liquefaciens*, *S. aureus*, *P. fragi*	[38]
848	Immunomodulatory function	[20]
OLL1073R-1	Reduces risk of catching common cold, anti-influenza virus activity	[21, 22, 39]
KLDS1-0207	Protects against lead toxicity	[31, 32]
BB18	Production of bacteriocin (bulgaricin BB18); bactericidal against *Helicobacter pylori*	[40]
ATCC 11 842, LBL-23, LBL-12, LBL-22, LBL-6, LBL-10, LBL-13, LBL-83, LBL-42, LBL-9, LBL-11	Inhibitory action against periodontal pathogen; *Aggregatibacter actinomycetemcomitans*	[41]
B-30892	Inhibits *Clostridium difficile*-mediated cytotoxicity on Caco2 cells	[42]
Commercial yogurt isolate	Inhibitory action against periodontal pathogens; *Porphyromonas gingivalis*, *A. actinomycetemcomitans*, and *Prevotella nigrescens*	[43]
Commercial yogurt isolate	Bacteriocin production inhibitory against *Vibrio cholerae* and *E. coli*	[28]
Commercial yogurt isolate	Inhibitory effect on *E. coli* O157:H7	[44]
NCTC 12197 Tat, DSMZ 20080 T	Inhibitory effects on *Salmonella* spp., *Pseudomonas aeruginosa*, *E. coli*, *S. aureus*	[45]
TLB06FT	Antibacterial activity against *E. coli*, *S. aureus*, *P. aeruginosa*, *Listeria monocytogenes*	[46]
CRL 454	Aids digestion of allergenic β-lactoglobulin	[47]
CRL 871	Production of folate; an alternative to folic acid fortification	[48]
761 N	Free radical scavenging ability; antiviral ability	[49]
GLB	Antimicrobial; control of *H. pylori*	[29]
GB N1 (48)	Hypolipidemic and protective cardiovascular effect	[54]
D6R; PTCC 1332	Inhibitory effects on *S. aureus* and *E. coli*	[27, 50]
F5R	Inhibitory effects on *Bacillus coagulans*, *B. cereus*, *P. fluorescens*, *K. pneumoniae*, *L. monocytogenes*, *S. aureus* and *E. coli*	[27]
DSM 20081	Inhibitory effect on *E. coli*	[51, 52]
DWT1	Inhibits tumor growth	[53]

Table 1.
Probiotic strains of Lactobacillus bulgaricus.

3. Conclusion

Because of the documented health benefits conferred by *L. bulgaricus*, consumer demand for yogurt and yogurt-related products has recently become the fastest growing dairy category in the global market. Our literature review showed that *L. bulgaricus* clearly qualifies as a probiotic in its own right. This growing popularity is not surprising in light of the fact that Nobel Laureate Metchnikoff linked the health and longevity of the Bulgarian people to their high consumption of yogurt containing *L. bulgaricus*. Consequently, increased yogurt intake should be a promising addition to a healthy dietary regimen that led to health promotion and well-being. Future work should be directed to understand the metabolites produced by *L. bulgaricus* and their health benefits. With a more comprehensive understanding on the functional properties of *L. bulgaricus*, we could advocate the importance of yogurt consumption and its impact on our well-being.

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References

[1] Bourlioux P, Pochart P. Nutritional and health properties of yogurt. World Review of Nutrition and Dietetics. 1988

[2] Chandan RC, Gandhi A, Shah NP. Yogurt: Historical background, health benefits, and global trade. In: Yogurt in Health and Disease Prevention. London: Academic Press; 2017. pp. 3-29. DOI: 10.1016/B978-0-12-805134-4.00001-8

[3] Gyawali R, Nwamaioha N, Fiagbor R, Zimmerman T, Newman RH, Ibrahim SA. The role of prebiotics in disease prevention and health promotion. In: Dietary Interventions in Gastrointestinal Diseases. United Kingdom: Academic Press; 2019. pp. 151-167

[4] Elmer GW, Martin SW, Horner KL, Mcfarland LV, Levy RH. Survival of *Saccharomyces boulardii* in the rat gastrointestinal tract and effects of dietary fiber. Microbial Ecology in Health and Disease. 1999;**11**(1):29-34

[5] Takahashi M, Taguchi H, Yamaguchi H, Osaki T, Komatsu A, Kamiya S. The effect of probiotic treatment with *Clostridium butyricum* on enterohemorrhagic *Escherichia coli* O157: H7 infection in mice. FEMS Immunology and Medical Microbiology. 2004;**41**(3):219-226

[6] Grigoroff S. Étude sur une lait fermenté comestible. Le "Kissélo mléko" de Bulgarie. Revue Médicale de la Suisse Romande. Genéve: Georg&G; LibrairesÉditeurs. Librairie de L'Université. 1905

[7] Song Y, Sun Z, Guo C, Wu Y, Liu W, Yu J, et al. Genetic diversity and population structure of *Lactobacillus delbrueckii* subspecies *bulgaricus* isolated from naturally fermented dairy foods. Scientific Reports. 2016;**6**:22704. DOI: 10.1038/srep22704

[8] Van de Guchte M, Penaud S, Grimaldi C, Barbe V, Bryson K, Nicolas P, et al. The complete genome sequence of *Lactobacillus bulgaricus* reveals extensive and ongoing reductive evolution. Proceedings of the National Academy of Sciences of the United States of America. 2006;**103**(24): 9274-9279. DOI: 10.1073/pnas.0603024103

[9] Michaylova M, Minkova S, Kimura K, Sasaki T, Isawa K. Isolation and characterization of *Lactobacillus delbrueckii* ssp. *bulgaricus* and *Streptococcus thermophilus* from plants in Bulgaria. FEMS Microbiology Letters. 2007;**269**(1):160-169. DOI: 10.1111/j.1574-6968.2007.00631.x

[10] Yılmaz R, Temiz A, Açık L, Çelebi Keskin A. Genetic differentiation of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* strains isolated from raw milk samples collected from different regions of Turkey. Food Biotechnology. 2015;**29**(4):336-355. DOI: 10.1080/08905436.2015.1092091

[11] Badis A, Guetarni D, Moussa Boudjema B, Henni DE, Kihal M. Identification and technological properties of lactic acid bacteria isolated from raw goat milk of four Algerian races. Food Microbiology. 2004;**21**(5):579-588. DOI: 10.1016/j.fm.2003.11.006

[12] Anukam KC, Reid G. Probiotics: 100 years (1907-2007) after Elie Metchnikoff's observation. Communicating Current Research and Educational Topics and Trends in Applied Microbiology. 2007;**1**:466-474

[13] Hawrelak JA, Myers SP. The causes of intestinal dysbiosis: A review. Alternative Medicine Review. 2004;**9**(2):180-197. DOI: 10.1016/0965-2299(93)90012-3

[14] Kulp WL, Rettger LF. Comparative Study of *Lactobacillus acidophilus* and *Lactobacillus bulgaricus*. Journal of Bacteriology. 1924;**9**(4):357-395 Retrieved from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC379059/

[15] Lick S, Drescher K, Heller KJ. Survival of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* in the Terminal Ileum of Fistulated Göttingen Minipigs. Applied and Environmental Microbiology. 2001;**67**(9):4137-4143. DOI: 10.1128/AEM.67.9.4137-4143.2001

[16] Elli M, Callegari ML, Ferrari S, Bessi E, Cattivelli D, Soldi S, et al. Survival of yogurt bacteria in the human gut. Applied and Environmental Microbiology. 2006;**72**(7):5113-5117

[17] Mater DDG, Bretigny L, Firmesse O, Flores M-J, Mogenet A, Bresson J-L, et al. *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* survive gastrointestinal transit of healthy volunteers consuming yogurt. FEMS Microbiology Letters. 2005;**250**(2):185-187. DOI: 10.1016/j.femsle.2005.07.006

[18] Vodnar DC, Socaciu C, Rotar AM, Stãnilã A. Morphology, FTIR fingerprint and survivability of encapsulated lactic bacteria (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*) in simulated gastric juice and intestinal juice. International Journal of Food Science and Technology. 2010;**45**(11):2345-2351. DOI: 10.1111/j.1365-2621.2010.02406.x

[19] Moro-Garcia MA, Alonso-Arias R, Baltadjieva M, Benitez CF, Barrial MAF, Ruisánchez ED, et al. Oral supplementation with *Lactobacillus delbrueckii* subsp. *bulgaricus* 8481 enhances systemic immunity in elderly subjects. Age. 2013;**35**(4):1311-1326. DOI: 10.1007/s11357-012-9434-6

[20] Dixon B. Secrets of the Bulgarian bacillus. The Lancet Infectious Diseases. 2002;**2**(4):260

[21] Makino S, Ikegami S, Kume A, Horiuchi H, Sasaki H, Orii N. Reducing the risk of infection in the elderly by dietary intake of yoghurt fermented with *Lactobacillus delbrueckii* ssp. *bulgaricus* OLL1073R-1. British Journal of Nutrition. 2010;**104**(7):998-1006. DOI: 10.1017/S000711451000173X

[22] Yamamoto Y, Fujino K, Saruta J, Takahashi T, To M, Fuchida S, et al. Effects of yogurt fermented with *Lactobacillus delbrueckii* ssp. *bulgaricus* OLL1073R-1 on the IgA flow rate of saliva in elderly persons residing in a nursing home: A before-after non-randomised intervention study. Gerodontology. 2017;**34**(4):479-485. DOI: 10.1111/ger.12296

[23] Ross RP, Morgan S, Hill C. Preservation and fermentation: Past, present and future. International Journal of Food Microbiology. 2002;**79**(1-2):3-16

[24] Cizeikiene D, Juodeikiene G, Paskevicius A, Bartkiene E. Antimicrobial activity of lactic acid bacteria against pathogenic and spoilage microorganism isolated from food and their control in wheat bread. Food Control. 2013;**31**(2):539-545. DOI: 10.1016/j.foodcont.2012.12.004

[25] Reis JA, Paula AT, Casarotti S, Penna A. Lactic acid bacteria antimicrobial compounds: Characteristics and applications. Food Engineering Reviews. 2012;**4**. DOI: 10.1007/s12393-012-9051-2

[26] Bachrouri M, Quinto EJ, Mora MT. Kinetic parameters of *Escherichia coli* O157: H7 survival during fermentation of milk and refrigeration of home-made yoghurt. International Dairy Journal. 2006;**16**(5):474-481

[27] Akpinar A, Yerlikaya O, Kiliç S. Antimicrobial activity and antibiotic

resistance of *Lactobacillus delbrueckii* ssp. bulgaricus and *Streptococcus thermophilus* strains isolated from Turkish homemade yoghurts. African Journal of Microbiology Research. 2011;**5**(6):675-682. DOI: 10.5897/AJMR10.835

[28] Tufail M, Hussain S, Malik F, Mirza T, Parveen G, Shafaat S, et al. Isolation and evaluation of antibacterial activity of bacteriocin produced by *Lactobacillus bulgaricus* from yogurt. African Journal of Microbiology Research. 2011;**5**(22):3842-3847

[29] Boyanova L, Gergova G, Markovska R, Yordanov D, Mitov I. Bacteriocin-like inhibitory activities of seven *Lactobacillus delbrueckii* subsp. *bulgaricus* strains against antibiotic susceptible and resistant *Helicobacter pylori* strains. Letters in Applied Microbiology. 2017;**65**(6):469-474. DOI: 10.1111/lam.12807

[30] Tongtawee T, Dechsukhum C, Leeanansaksiri W, Kaewpitoon S, Kaewpitoon N, Loyd RA, et al. Improved helicobacter pylori eradication rate of tailored triple therapy by adding *Lactobacillus delbrueckii* and *Streptococcus thermophilus* in northeast region of Thailand: A prospective randomized controlled clinical trial. Gastroenterology Research and Practice. 2015;**2015**:518018. DOI: 10.1155/2015/518018

[31] Fewtrell LJ, Prüss-Üstün A, Landrigan P, Ayuso-Mateos JL. Estimating the global burden of disease of mild mental retardation and cardiovascular diseases from environmental lead exposure. Environmental Research. 2004;**94**(2):120-133. DOI: 10.1016/S0013-9351(03)00132-4

[32] Li B, Jin D, Yu S, Etareri Evivie S, Muhammad Z, Huo G, et al. In vitro and in vivo evaluation of *Lactobacillus delbrueckii* subsp. *bulgaricus* KLDS1.0207 for the alleviative effect on lead toxicity. Nutrients. 2017. DOI: 10.3390/nu9080845

[33] Alazzeh AY, Ibrahim SA, Song D, Shahbazi A, AbuGhazaleh AA. Carbohydrate and protein sources influence the induction of α- and β-galactosidases in *Lactobacillus reuteri*. Food Chemistry. 2009;**117**(4):654-659

[34] Ibrahim SA, Gyawali R. Lactose intolerance. In: Young P, George H, editors. Milk and Dairy Products in Human Nutrition: Production, Composition and Health. Iowa, IA: John Wiley & Sons; 2013. pp. 246-256

[35] de Vrese M, Stegelmann A, Richter B, Fenselau S, Laue C, Schrezenmeir J. Probiotics—compensation for lactase insufficiency. The American Journal of Clinical Nutrition. 2001;**73**(2):421s-429s. DOI: 10.1093/ajcn/73.2.421s

[36] Kechagia M, Basoulis D, Konstantopoulou S, Dimitriadi D, Gyftopoulou K, Skarmoutsou N, et al. Health benefits of probiotics: A Review. ISRN Nutrition. 2013;**2013**:481651. DOI: 10.5402/2013/481651

[37] Singh J, Khanna A, Chander B. Antibacterial activity of yogurt starter in cow and buffalo milk. Journal of Food Protection. 1979;**42**(8):664-665

[38] Abdel-bar NM, Harris ND. Inhibitory effect of *Lactobacillus bulgaricus* on psychrotrophic bacteria in associative cultures and in refrigerated foods. Journal of Food Protection. 1984;**47**(1):61-64

[39] Nagai T, Makino S, Ikegami S, Itoh H, Yamada H. Effects of oral administration of yogurt fermented with *Lactobacillus delbrueckii* ssp. *bulgaricus* OLL1073R-1 and its exopolysaccharides against influenza virus infection in mice.

International Immunopharmacology. 2011;**11**(12):2246-2250

[40] Simova E, Beshkova D, Najdenski H, Frengova G, Simov Z, Tsvetkova I. Antimicrobial-producing lactic acid bacteria isolated from traditional Bulgarian milk products: Inhibitory properties and in situ bacteriocinogenic activity. In: Proceedings of the IUFoST, 13th World Congress Food Sci Technol "Food is life". 2006. pp. 17-21

[41] Stamatova I, Kari K, Meurman JH. In vitro evaluation of antimicrobial activity of putative probiotic lactobacilli against oral pathogens. International Journal of Probiotics and Prebiotics. 2007;**2**(4):225

[42] Banerjee P, Merkel GJ, Bhunia AK. *Lactobacillus delbrueckii* ssp. *bulgaricus* B-30892 can inhibit cytotoxic effects and adhesion of pathogenic *Clostridium difficile* to Caco-2 cells. Gut Pathogens. 2009;**1**:8. DOI: 10.1186/1757-4749-1-8

[43] Zhu Y, Xiao L, Shen D, Hao Y. Competition between yogurt probiotics and periodontal pathogens in vitro. Acta Odontologica Scandinavica. 2010;**68**(5):261-268

[44] Fooladi AAI, Forooshai MC, Saffarian P, Mehrab R. Antimicrobial effects of four lactobacilli strains isolated from yoghurt against Escherichia coli O157: H7. Journal of Food Safety. 2014;**34**(2):150-160

[45] Nour I, Fattouh F, El-Adawi H. Antibacterial bioactivity of selected lactic acid bacterial strains against some human pathogenic bacteria. International Journal of Pharmacology. 2015;**11**(5):440-447

[46] Mahmood T, Masud T, Ali S, Sarfraz Abbasi K, Liaquat M. Optimization and partial characterization of bacteriocin produced by *Lactobacillus bulgaricus-TLBFT06* isolated from Dahi. Pakistan Journal of Pharmaceutical Sciences. 2015;**28**

[47] Pescuma M, Hébert EM, Haertlé T, Chobert J-M, Mozzi F, de Valdez GF. *Lactobacillus delbrueckii* subsp. *bulgaricus* CRL 454 cleaves allergenic peptides of β-lactoglobulin. Food Chemistry. 2015;**170**:407-414

[48] Laiño JE, Hebert EM, de Giori GS, LeBlanc JG. Draft genome sequence of *Lactobacillus delbrueckii* subsp. *bulgaricus* CRL871, a folate-producing strain isolated from a northwestern Argentinian yogurt. Genome Announcements. 2015;**3**(3):e00693-e00615

[49] El-Adawi H, Nour I, Fattouh F, El-Deeb N. Investigation of the antiviral bioactivity of *Lactobacillus bulgaricus* 761N extracellular extract against hepatitis C virus (HCV). International Journal of Pharmaceutics. 2015;**11**:19-26

[50] Tebyanian H, Bakhtiari A, Karami A, Kariminik A. Antimicrobial activity of some *Lactobacillus* species against intestinal pathogenic bacteria. International Letters of Natural Sciences. 2017

[51] Ravindran L, Manjunath N, Darshan RP, Manuel SGA. In vitro study analysis of antimicrobial properties of lactic acid bacteria against pathogens. Journal of Bio Innovation. 2016;**5**(2):262-269

[52] Abedi D, Feizizadeh S, Akbari V, Jafarian-Dehkordi A. In vitro anti-bacterial and anti-adherence effects of *Lactobacillus delbrueckii* subsp *bulgaricus* on *Escherichia coli*. Research in Pharmaceutical Sciences. 2013;**8**(4):260-268. Retrieved from: https://www.ncbi.nlm.nih.gov/pubmed/24082895

[53] Guha D, Banerjee A, Mukherjee R, Pradhan B, Peneva M, Aleksandrov G,

et al. A probiotic formulation containing *Lactobacillus bulgaricus* DWT1 inhibits tumor growth by activating pro-inflammatory responses in macrophages. Journal of Functional Foods. 2019;**56**:232-245

[54] Doncheva NI, Antov GP, Softova EB, Nyagolov YP. Experimental and clinical study on the hypolipidemic and antisclerotic effect of *Lactobacillus bulgaricus* strain GB N 1 (48). Nutrition Research. 1 April 2002;**22**(4):393-403

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The dairy industry has faced several challenges that have impacted dairy food quality and consumer acceptability. This book presents a different approach to address current issues and challenges facing the dairy industry. The book consists of seven chapters dealing with dairy processing, current issues related to consumers, and probiotic characteristics. We hope that this first edition can build interest among other scientists to join our future effort to write a more comprehensive book on this topic.

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