

TRADITIONAL CHEESE PROCESSING: FOOD SAFETY LESSONS AND
INTERVENTIONS IN THE INFORMAL DAIRY SECTOR

By

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ABSTRACT

Consumer preference surveys in many developing regions have revealed low confidence for traditional dairy products because of perceived poor safety and unhygienic practices of the processors, especially those who are low literate. Many of these products are therefore restricted to informal settings, and traditional product certification is rare. The study examines the current state of knowledge, attitudes, and practices among female cheese processors in cattle rearing villages in Southern Ghana. Semi-structured, one-on-one interviews combined with on-site observations were conducted during a mini survey. The results showed that traditional cheese processors were conversant with process controls, non-processing and processing factors that could influence the quality of their products but did not consider safety and hygiene as a critical factor. Many of the processors had poor knowledge, incorrect attitudes, and were engaged in suboptimal practices that were likely to result in poor product safety and quality.

Wagashie is the name of the fresh unripened soft cheese produced by Ghanaian traditional cheese makers. To study the effects of some processing factors that traditional processors believed influenced certain physicochemical attributes of *Wagashie*, processing was replicated on a laboratory scale with some modifications. A 3 x 3 full factorial design was used to study the effects of added salt (0.03%, 0.10% & 0.50%) and length of exposure (20 mins, 30 mins & 40 mins) of cooked curds to constant heat (75°C). The results showed that the moisture, fat and protein content of cheese curds decreased significantly ($p < 0.05$) with increased salt. The increased curd cooking time also improved cheese yield and decreased syneresis. The pH of the cheese curds was not significantly influenced by either factor and therefore may not serve as an important process control indicator for this cheese type.

An intervention in the form of a scientific animation was created to test the understanding of basic food safety and hygiene concepts during *Wagashie* processing. The animation also contained brief education on the benefits of increased salt and prolonged curd cooking. The information in the animation was screened by food safety experts for accuracy and conciseness and translated into three Ghanaian languages (Fulani, Hausa and Ga-Adangbe) based on the languages spoken by the participants of the study. The results of the training showed a significant improvement in the knowledge and attitudes of traditional cheese processors regarding food safety and hygiene during processing.

Keywords: dairy processor, hygiene, food safety, knowledge assessment, cheese processing, physicochemical qualities, scientific animations.

This work is devoted to actors in informal food supply chains who may feel their contributions to achieving food security are not noticed.

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BACKGROUND TO THE STUDY

Smallholder dairy processing activities are evident in the types of local dairy products available in informal market systems. In deconstructing the dairy supply chain, it starts on small-scale family-owned dairy farms, then raw milk subsequently undergoes some form of processing into cheese or yogurt and then products are retailed in local food service or wet markets. The importance of such small-scale dairying is evident in several socio-economic spheres. For example, smallholder dairy farmers in East Africa supply individual households and contribute to the bulk of raw milk supply in the dairy value chain. These efforts have been shown to produce diversified and higher annual incomes, and therefore allow smallholders to have resilience to food and nutrition insecurity (Banda et al, 2021). Another example from India by Jaiswal et al (2018) shows that the involvement of resource poor households in dairying reduces the disparity in holding resources and boosts nutritional intake by members of the household.

There are opportunities to develop the small-scale dairy sector in developing countries. Currently the marketing of dairy products is based on the local demand for processed dairy products. Mechanisms to improve milk collection, commingling, testing, and retail are almost nonexistent in the informal marketing system. According to the Food and Agricultural Organization (FAO, 2023) this may partly be due to consumer choices and preferences to be unwilling to pay for rigorous processing and packaging costs. In addition, developing countries often lack resources and data needed to define standards leading to non-compliance issues and tradeoffs with food safety regulations (Grace et al, 2020). As a result, there is poor monitoring of the quality of traditional dairy products and a possible threat to public health.

The lack of data from certain actors in the dairy supply chain in developing countries may have contributed to the inability to improve the sector. There are several studies showing the prevalence of food borne diseases arising from traditional dairy products. For example, studies

conducted by Berhe et al. (2020) reported up to 52% of samples contaminated with bacteria in the milk value chain in Tigray, Northern Ethiopia, with contamination increasing once products have left the dairy farm. Various biological hazards of public health concern have also been reported to be found in dairy products from Kenya, Libya, Tanzania, and Nigeria (Grace et al, 2020). Tracing the source of these contaminants is often conducted during these studies, however, the circumstances pertaining to each actors' contributions are often not well understood.

According to Omore et al. (2009), among different actors in the dairy chain, contributing factors to some of the concerns raised can include the lack of infrastructure, poor communication, improper transportation modules, distance to markets and the use of low-cost technologies that may not improve the shelf-life of dairy products. In this exploratory study, we delve into smallholder cheese processing using Southern Ghana as a case study. We focus on cheese processors as actors who are often overlooked as important contributors to the dairy value chain. The study attempts to document constraints to processing that may be unintentionally creating food safety risks to both consumers and other actors. It is believed that by conducting this research, inefficiencies in milk sourcing, cheese processing and retailing can be addressed to improve access to markets and create sustainable livelihoods for the smallholder dairying sector.

CHAPTER ONE: LITERATURE REVIEW

1.1 DOMESTIC DAIRY PRODUCTS VERSUS DAIRY IMPORTS

In trying to explore if dairy imports were creating competition for domestic dairy production, several studies were conducted in developing countries. The findings were that, starting in the early 80s dairy imports of cheaper and subsidized intermediate products, primarily milk powder, butter oil and condensed milk grew in developing countries, but mixed results showed the imports served different purposes and the competition was rarely nationwide. For example, a descriptive study by Knips (2006) showed that while the imports supplemented supply shortages in Senegal, Jamaica, and Bangladesh, Tanzania's imports had decreased as local dairy consumption increased, and Peru and Thailand had introduced tariffs that had caused the reduction of imports. In another example, an assessment of dairy trade in developing countries by Cox and Zhu (2004) showed that the lack of resources to expand milk production in the Middle East and North Africa and food insecurity in some South Asian countries caused increased importation. The importance of such studies was that dairy imports were mainly intermediate products that supplemented supply-side shortages and enhanced product differentiation, but the country studies did not give a real indication of what shares were going to different types of dairy processors. In effect, these studies did not address what effect the imports had on the processing behavior of multinational, modern or traditional dairy processing firms.

Much later, modern dairy production started to increase in developing countries, but the consumption of traditional dairy products was still significant. For example, in India, Jesse et al (2006) found that local consumption was driven by the dominating small-scale sector who receive 51% of milk sold for processing fluid milk and local milk products, while government-supported organized cooperatives and companies, received only 17%. Again, in most countries of Sub-Saharan Africa, Mbogoh (1984) found that consumers drove marketing trends. Many modern and

multinational firms sold modern products to urban consumers through formal marketing systems while low-cost traditional operations catered mostly to rural consumers through informal channels. The importance of this was that, the nature of imports was not finished products, but different types of dairy processing operations differentiated products into useful finished products to meet consumer demands, however, this did not reduce the demand for traditional products. The unanswered question was what consumers looked out for in choosing between modern and traditional dairy products; product attribute or processor type?

1.2 THE SAFETY OF MILK AND MILK PRODUCTS

Dairy products may contain hazards that are of a biological, physical, or chemical nature and can occur at any point of the dairy supply chain. Examples of physical hazards are insect and soil fragments likely to cause harm, while chemical hazards may consist of antibiotics, nitrates, and pesticides (Keskin and Gulsunoglu, 2012). Microbial hazards pose the greatest risk to the safety of dairy products. Examples of these hazards prevalent in developing countries include *Mycobacterium bovis*, *Brucella abortus* and *Listeria monocytogenes*. The microbial quality of milk and milk products depends on several factors including milk production, storage factors, chemical composition as well as initial microbial and somatic cell counts. A review by Fusco et al (2020), explained that the rich nutritional environment of milk as a base ingredient for other dairy products makes it susceptible to all types of bacteria especially those of a proteolytic, lipolytic, or psychrotrophic nature. The authors add that although pasteurization temperatures are targeted at *Coxiella burnetii*, it is worthy to note that poor hygienic practices have historically led to the survival of pathogens of public health significance, at various stages of the supply chain, like *Salmonella spp*, *Listeria monocytogenes*, *Escherichia coli* O157:07, coagulase-positive *Staphylococcus*, etc.

It should also be noted that the control of microbial hazards during dairy processing differs significantly based on the setting, whether conducted on an informal or industrialized basis, as well as the operational scale. In traditional/ informal settings, milk may be sold with or without processing based on the target consumer. Owusu-Kwarteng et al (2020) identified microbial risk factors in the dairy processing chain in Africa because of some of the following factors: poor animal production practices, unhygienic milk collection practices, unavailability or inefficiency of cold storage facilities, inappropriate packaging material, and problems with transportation and

distribution of products. The study also noted that unregulated fermentation practices and poor processor hygiene were the main risk factors for the poor safety of traditional dairy products. Traditional dairy processing is highly unstandardized and therefore several of these risk factors may be a result of poor knowledge, location of the processor operation, or the lack of proper facilities and training. Unfortunately, this reduces the acceptability of the products to a large extent.

1.3 FOOD REGULATIONS AND QUALITY ASSURANCE

According to the Food and Agricultural Organization (FAO), Food Regulations are a set of legal frameworks that governments mandate across a food supply chain to ensure quality and safety and to guarantee that the consumer is not defrauded or exposed to illness. Apart from National regulations, countries also follow standards set by the World Trade Organization and Codex Alimentarius to meet international benchmarks. Consumer demands for credence attributes may also allow regulations that bind certain production and processing practices leading to voluntary certification schemes. The United States Food and Drugs Authority is backed by the Public Health Service Act and the Food, Drug, and Cosmetic Act that allow it to issue guidance and regulatory information. In general, several quality assurance programs exist to help manage risks along the food supply chain such as Good Agricultural Practices, Good Manufacturing Practices, Hazard Analysis and Critical Control Points, Hazard Analysis and Risk-Based Preventive Controls, etc. Each of these programs is often drafted to suit certain operational capacities with modifications to meet processing operations with special needs.

Globally, standards for most milk and milk products are set by international bodies like the World Trade Organization and Codex Alimentarius while regulations for the entire supply are guided by several organizations. With reference to the US National Research Council Subcommittee on Microbiological Criteria (1985), fluid milk and other dairy products received the most initial attention for control of bacteria during processing and storage because of their role in the transmission of foodborne illness, with the milk sanitation program being one of the oldest Public Health Service records. Currently, the revised Grade A Pasteurized Milk Ordinance developed by the US Public Health Service and US FDA assisted by the National Conference on

Interstate Milk Shippers is used to guide milk and milk product handling and processing in the USA.

1.4 GHANA'S FOOD SAFETY REGULATIONS

Ghana's Public Health Act of 2012, Act 851, authorizes the Ghana Food and Drugs Authority (GFDA) to ensure the safety of food and drugs that are consumed by the public within the country. With reference to Ashitey (2017), Ghana's food laws mandate that all food products that are manufactured, distributed, imported, advertised, or sold must be registered with the GFDA. The GFDA's Food Safety Division executes the law as well as provides technical support to the food industry. Ghana also has a Food Safety Policy developed in conjunction with several National Stakeholders and supported by the World Health Organization and the Food and Agricultural Organization.

According to Asante et al (2020), the GFDA has a code of hygienic practice (FDA/FSMD/CP-FSE/2013/03) that ensures compliance with hygienic practices during food preparation, packaging, distribution, storage, and retail but there are a lot of challenges with implementing these recommendations in the food processing sector which is heavily dominated by micro and small to medium scale enterprises, and mainly operate in the informal sector. The authors also acknowledge that the development of the National Food Safety Policy does not fix the problem of the adoption of food safety practices by the actors in the informal or traditional food processing sector. Research conducted by Ababio et al (2016), comparing compliance to safety standards in the UK and Ghana showed that lack of training and useful equipment among the informal food processing sector presents several constraints for complying with good hygienic practices stipulated by the GFDA.

1.5 MAJOR TRADITIONAL DAIRY PRODUCTS IN GHANA

With reference to Kunadu et al (2019), the most consumed traditional dairy products in Ghana include freshly boiled milk, “*Nunu/Nyaame*”- a spontaneously fermented milk drink, “*Brukina*” - a mixture of “*Nunu*” and boiled millet and “*Wagashie*” -an unfermented soft cheese product. Processing is mostly done by women on a small scale (Omore, 2004; Gidiglo, 2014), who often use non-standardized processing techniques for production.

Fermented milk (*Nunu* or *Nyarmie*) is a highly valued product in Africa because of the low energy input required and high nutritional value, but microbial cultures involved in the production may depend on the climatic conditions of the geographical area in question (Mattiello et al., 2018). Akabanda et al (2014) successfully isolated lactic acid bacteria from spontaneously fermented *Nunu* to produce pure cultures that could help standardize the traditional production via controlling the process of fermentation. Although the study resulted in producing a product with desirable sensory properties, traditional production is still very variable because of poor knowledge of the developed technology. This means the product is still susceptible to poor quality. Although Akabanda et al (2010) found that Enterobacteriaceae hardly survive in the product at the end of fermentation because of low pH levels, Owusu-Kwarteng et al (2018) found that 13% of *Nunu* samples collected from a sample of traditional dairy farmers in the Northern Region of Ghana tested positive for *Listeria monocytogenes*. There are no further studies investigating the source of contamination for this type of product, but the authors attributed it to uncontrolled and unsanitary processing environments.

Brukina has been described by Baidoo and Kunadu (2018) as a fermented milk and millet smoothie that originated from Northern Ghana but has gained widespread popularity across the country with a reputation as being a complete meal with minute differences in processing based

on consumer/processor preference. A Standard Operating Protocol to produce *Brukina* developed by Baidoo and Kunadu (2018) led to the reduction of coliforms and *Staphylococcus aureus* that was prevalent in commercial samples, however, this was tested on a lab-scale and not disseminated. Changes in microbial content during storage by Ampofo-Asiamah et al (2020) showed that refrigerated temperatures were useful for prolonging the microbial quality of the product, but refrigeration could also be useless if the initial microbial load is high after processing or assuming processing is done in an unhygienic environment.

Wagashie is a fresh cheese product consumed in Ghana as a snack or animal protein alternative in the diet. It is very popular in the West African region. Traditionally, it is made using cow's milk and plant extracts as a coagulant. Popular coagulants used across the West African region include *Calotropis procera* and *Carica papaya* (Adetunji and Salawu, 2008). Owing to its short shelf stability, some attempts have been made to optimize traditional processing with varying results. For example, Arthur (2016) studied fermentation and smoking as processing parameters to improve safety and shelf stability. Tohibu et al (2013) also attempted to preserve the chemical properties of *Wagashie* using vacuum packaging. In this current study, the processing parameters involved in *Wagashie* processing are further studied.

1.6 CERTIFICATION PROCESS FOR TRADITIONAL FOOD PROCESSORS

To help mitigate the challenges listed in section 1.4, in July 2020, the GFDA launched a Progressive Licensing Scheme (PLS) with provision for retail access to formal marketing outlets. Although this initiative is targeted at improving licensing and registration for traditional food processors, the GFDA checklist does not appear to be suited to the needs of the processors (FDA/FSM/FOR-07) and is more geared towards food service establishments. Access to training information on the GFDA website was not available at the time of this review. It is therefore noted that access to information for compliance with food safety measures is restricted and almost impossible for traditional food processors.

1.7 THE USE OF ANIMATIONS FOR TECHNOLOGY TRANSFER TO LOW LITERATE LEARNERS

Technology transfer is the process of delivering valuable information, skills, and technology gained through research to beneficiaries. Several transfer models exist, depending on the information and the target beneficiaries. In all cases, it is important for appropriate dissemination and decentralization, associated with great communication, coordination, and knowledge sharing among all the actors involved (Audretsch et al, 2012). The food industry in developing regions benefits a lot from technology transfer through improvements to either products, production processes, or both. According to Thammarutwasik (2008), small to medium scale enterprises have the chance of improving the nutrition, safety, and convenience of products particularly through training on technical know-how, using written instructions, design drawing, prototypes, or a combination of these.

According to Ainsworth (1999), educational animations are possible ways of increasing motivation among learners and may be designed to serve different learning objectives. With appropriate use, animations can be indispensable tools for technology transfer. With reference to Uquiza-Fuentes and Velazquez- Iturbide (2013), animation viewing for learning may take different forms, with evaluations for each form often yielding different results. Visualizations may be static or in-motion. Although each mode has its own advantages and disadvantages, Lin and Li (2018) are of the view that animations in motion may be a better alternative due to their ability to illustrate conceptual changes, procedures, and dynamic processes and provide external scaffolding for learners to build correct mental models regarding learned knowledge while avoiding possible incorrect inferences from static models.

Low-literate learners involved in skilled work often learn by practical training and may miss out on technological know-how due to several barriers including language and lack of access to formal education. In the food industry, several smallholder processors are disadvantaged from using improved technologies that could boost their economic growth and competitiveness among other food industry players for such reasons. Using animations, however, may serve as a means to successfully transfer new knowledge to smallholder food processors.

1.7.1 Scientific Animations without Borders (SAWBO)

The tools for disseminating new knowledge and technologies among low-literate learners play a vital role in how the information is received, evaluated, and adopted by the learner. According to Mills and Wake (2017), many low-literate learners are in rural communities, speak local languages, and have very limited access to expert knowledge existing in global research and educational communities. With advancements in technology, reaching low-literate learners has attained new heights and offered more opportunities for self-efficacy, as well as attaining set objectives for technological transfer. Scientific Animations without Borders (SAWBO) was particularly created to increase knowledge access among low-literate learners using animations in local languages and dissemination via basic cell phones without the need for online streaming. Creators of SAWBO developed this cost-effective method based on years of research that identified gaps and incompetencies in the ways scientific knowledge was communicated, particularly to low-literate learners in several parts of the developing world.

The SAWBO approach involves first identifying the topic area, establishing contact with global and local experts for the creation of accurate content, translating content into target appropriate languages, and disseminating the information for free. SAWBO has successfully used

its approach to disseminate useful scientific knowledge to appropriate audiences to improve and sustain livelihoods.

Scientific Animations Without Borders (SAWBO) is a university based program that “transforms extension information on relevant topics such as agriculture, disease and women's empowerment, into 2D, 2.5D and 3D animations, which are then voice overlaid into a diversity of languages from around the world” (SAWBO, 2023). Founded in 2010, SAWBO undertook to scientifically investigate means for effectively delivering science-based, best-practices educational information, primarily to adult learners in developing nation contexts (Bello-Bravo et al., 2010). This goal was informed both by sustainable development’s emphasis on prioritizing meeting the needs of the world’s poorer (Brundtland et al., 1987) but also the recognition that successfully delivering educational messaging in the most difficult contexts (including multiple languages, low to no literacy, largely rural or remote locations, and areas with undeveloped infrastructures) would likely ensure reaching populations in less straitened situations (Bello-Bravo & Pittendrigh, 2018).

Beginning from adult and multimedia educational principles (Knowles et al., 2012; Lowe & Schnotz, 2014; Mayer, 2002; Moreno & Mayer, 2002), early practical lessons affirmed by SAWBO’s research included the necessity of being able to easily translate educational videos into locally most comfortably spoken languages (Bello-Bravo & Baoua, 2012), the appeal and cost-effectiveness of animated (as opposed to live-action) video content (Bello-Bravo, Dannon, et al., 2013), and strategies for overcoming infrastructure delivery limitations using information and communication technologies (ICTs), especially video-enabled mobile phones (Bello-Bravo, Nwakwasi, et al., 2013). Throughout this research for what was dubbed mobile Education for Sustainable Development (mobile ESD), the critical importance of reaching women and not

excluding indigenous populations was also a central emphasis (Bello-Bravo, 2019; Bello-Bravo et al., 2019; Bello-Bravo & Pittendrigh, 2012; Lutomia & Bello-Bravo, 2017).

By 2018, two key milestones for mobile ESD had been reached: (1) classical pretest/posttest comparisons of learning gains by traditional extension and animated video approaches demonstrated not only greater learning gains for animated video delivery but also no statistically significant differences in learning measures by age, gender, or educational and technological literacy (Bello-Bravo, Tamò, et al., 2018; Bello-Bravo, Zakari, et al., 2018; Mocumbe, 2016); (2) a two-year follow-up on previous training for an improved postharvest loss prevention protocol measured a 93% knowledge retention and 89% solution-adoption by participants, and instances of *reinvention* (adaption and changes to the protocol) that caused no failure of the storage method (Bello-Bravo, Abbott, Mocumbe, Mazur, et al., 2020; Bello-Bravo, Abbott, Mocumbe & Pittendrigh, 2020; Mocumbe, 2016). These outcomes taken together suggest the ability of mobile ESD to impart science-based educational information and elicit solution adoption and buy-in to that information by people regardless of age, gender, and levels of education and technical literacy.

Background “support” for mobile ESD was researched and implemented throughout as well. In terms of enabling people’s access to mobile ESD videos, all are freely archived and hosted on SAWBO’s website as a Library, an Android phone deployer App has been developed, and digital copies of the Library have been made for distribution (Bello-Bravo & Pittendrigh, 2018; Rodríguez-Domenech et al., 2019). Critically, because the technological hindrances of unstable or nonexistent electrical grids, limited or lack of Internet access in geographically remote areas, and prohibitive costs of data plans and Internet access (Bello-Bravo et al., 2022; Oludimu, 2019), increasing access will often involve an individual change agent’s or organization’s choosing from

available videos and then using mobile phones, Bluetooth-sharing and other technologically small-footprint means for presenting information (Bello-Bravo, Lutomia, et al., 2020); one organization in Bangladesh offered 1,080 spontaneous (pop-up) agricultural extension trainings to more than 131,000 participants (averaging 123 participations per pop-up) (Medendorp et al., 2022).

As a learning-systems approach, SAWBO has built up its organizational infrastructure to incorporate feedback loops over the whole length of value chains (including recipient feedback) (Bello-Bravo et al., 2021), libraries of animation assets for ease of modifying animated content and responding quickly to emergencies like insect pest invasions and COVID-19 (Bello-Bravo, Huesing, et al., 2018; Whitmore, 2020, 22 September), and most essentially, strategies for easily, quickly, and inexpensively translating existing content into new languages as needed, effectively affording the mass-upscaling of ICT content at decreasing unit costs to scale (Bello-Bravo et al., 2022).

1.8 RESEARCH GAPS AND ANALYTICAL FRAMEWORK

Firstly, previous studies have shown low consumer confidence in traditional dairy products mainly due to safety issues. However, studies that look at food processing from the point of view of traditional processors are rare. There are few attempts to understand and address the factors that influence food safety practices of traditional dairy processors, especially considering their operational scale. As a result, there has been failure to identify risk behavior and processing variables that may help refine critical control points and enhance overall product quality. Secondly, in the cheese making process, there are often several process controls that are implemented to guarantee the consistent quality of the products. These include monitoring the nutritional composition of milk depending on the cheese type, monitoring processing parameters like acidity, salt content, cooking time and temperature, as well as regulating conditions under which curds are treated to maintain standards of identity. It is unclear in literature the potential factors that affect the integrity of the renneted cheese curd of *Wagashie* in particular. Thirdly, there are several recommendations to train food processors on food safety principles. However, formal training does not appear to be attainable for the informal food supply chain. There is a general lack of innovative interventions that are suited to the needs of non-literate dairy processors.

Given the identified gaps, the following are the research objectives of the current study.

1. To assess the food safety and hygiene knowledge, attitudes, and practices of traditional cheese processors in Ghana.
 - a. Research question: Are there differences in the food safety and hygiene knowledge, behavior, perceptions and practices of different traditional dairy processors in Ghana?

2. To determine the effects of critical process controls on the physicochemical composition of *Wagashie* using traditional processing protocols
 - a. Research question: What minimal interventions can improve the qualities of *Wagashie* that are important to the cheese processor?
3. To create a scientific animation for training traditional cheese processors
 - a. Research question: Is a scientific animation on food hygiene and safety practices effective for adopting good hygienic practices among traditional dairy processors?

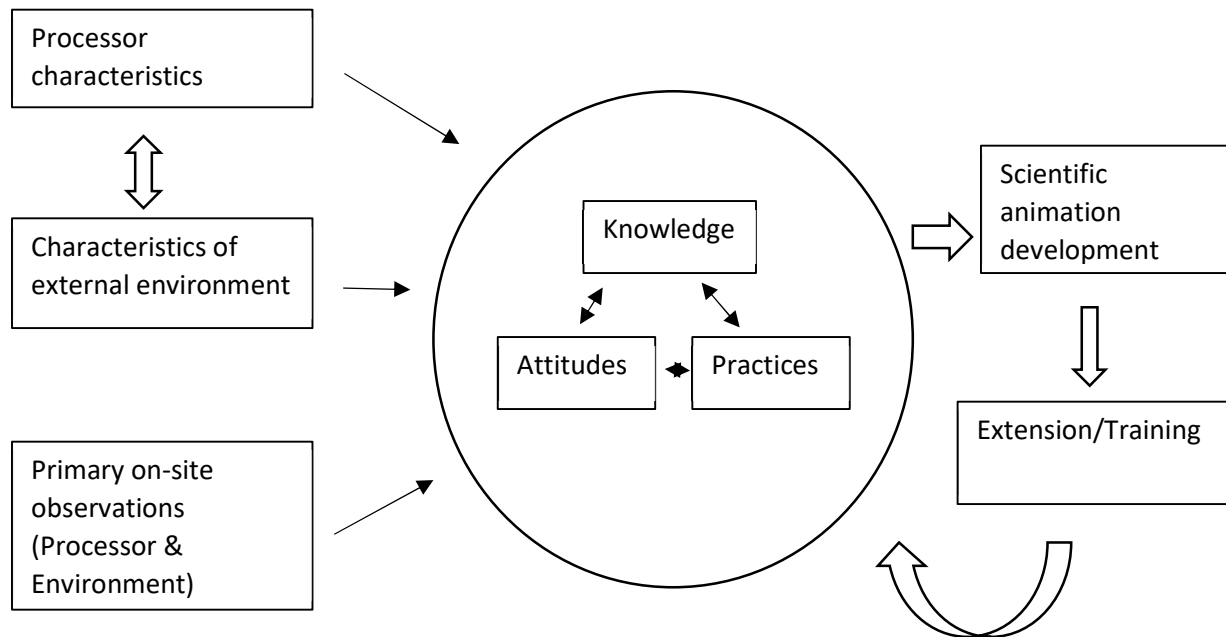


Figure 1.1: Analytical framework showing influences of intrinsic and extrinsic variables (processor and environmental characteristics, on-site observations) on interactions among processor knowledge, attitudes and processors, and the influence of extension on all three dependent variables (Modified from Meijer et al, 2015)

**CHAPTER TWO: A QUALITATIVE ASSESSMENT OF TRADITIONAL CHEESE
PROCESSORS IN GHANA (Adam & Bello-Bravo, 2022)**

2.1 INTRODUCTION

Traditional dairy processing in many developing countries is underdeveloped but contributes significantly to the diet and livelihoods of consumers and processors, respectively. The continued growth and presence of modern dairy processing firms led to consumer preference surveys for local modern and traditional dairy products. In many developing countries, the findings showed that consumers resorted to modern products for the same dairy product category because of their perceived safety, but valued traditional products for their taste, lower price, and perceived superior nutrition. For example, consumer surveys by Staal et al. (2008) in Kenya and Ethiopia showed that traditional products had poorer microbial quality but were preferred over modern products because both high-income and resource-poor consumers preferred the tastes and affordability, respectively. Another study in Ghana's capital by Kunadu et al. (2019) revealed that consumer confidence was often higher for multinational dairy brands due to perceptions of poor processing practices and poor safety among traditional dairy processors and these perceptions may influence purchasing and consumption patterns and potentially influence intervention efforts to boost the traditional dairy industry.

Indeed, several microbial studies have found that the level of pathogens in dairy products depends on whether processors control hazards (before, during, or after processing) or are a well-known consumer brand or not. For example, an evaluation of the microbial quality of fifty-five (55) raw milk cheese samples produced by small farms with no safety protocols and commercial deli markets with safety protocols in parts of Brazil by Moraes, et al. (2009) showed higher levels of pathogenic microbes than the legally allowable limits in all samples at the point of retail. In Jordan, a similar study by Gharaibeh (2017) of eight (8) branded and unbranded *Labneh* cheese samples collected from local markets showed significant differences in the levels of pathogens. Unbranded *Labneh* had higher than the legal limits for coliforms, yeast, and mold, while branded

ones were microbiologically acceptable. In summary, although the microbial content of both modern and traditional products may be controlled during processing, less standardization of procedures for traditional dairy products may make them unsafe.

Implementing food safety practices among traditional dairy processors often needs education and training on food safety principles. However, different sized firms often have different compliance expectations, depending on the type of food safety program. For example, in the USA (United States), several authorities (such as the Food and Drugs Authority (FDA), Center for Disease Control (CDC), United States Department of Agriculture (USDA), and Environmental Protection Agency (EPA) handle different sections of the food supply chain to control contamination but often require training to be conducted and evaluated by trained and certified individuals. State regulatory authorities are also responsible for handling the safety of milk and milk products in the USA. Local food authorities also conduct food safety training for different sized firms in many developing countries. However, such modes of education or training can be ineffective for traditional processors who are non- or low literate, depending on the mode of delivery. Omore et al. (2009), upon a thorough analysis of dairy products processing in Ghana and Tanzania, concluded that several opportunities existed for intervention, particularly with marketing, public health issues, and indigenous processing.

In legally regulated cheese processing industries, several process controls are often implemented to guarantee the safety and consistent quality of the products. These include monitoring the nutritional composition of milk depending on the cheese type, monitoring acidity, salt content, cooking time and temperature, and regulating conditions under which curds are treated to maintain standards of identity. However, traditional cheese processing, especially in low-income countries, may be done under low regulations, the absence of standards and

documentation, and relying on generational knowledge (Omore et al., 2009; Owusu-Kwarteng et al., 2020; Paxson, 2013). There are very few studies evaluating the food safety behavior of traditional processors considering the dendritic nature of the dairy supply chain and individual factors (process controls or otherwise) that may affect their processing outcome. Traditional dairy products are also thought to be made by processors with little or no Food Science knowledge and have different target markets and access. However, the broader consumer consensus is that traditional products are unsanitary. This study's overarching goal is to assess the adoption of food safety and hygiene practices by interacting with traditional cheese processors in cattle rearing villages in Southern Ghana and use the information to build a food safety training program that may improve their processing scale and conditions. More specifically, the study seeks to determine if there is an inter-processor difference or not in process controls that are implemented, how they are implemented at such operational levels are and whether these opinions affect the quality of traditional cheese products marketed in Ghana. It is hypothesized that traditional dairy processors are not conducting their activities in line with well-established local and international processing standards that have been proven critical for product safety.

2.2 METHODS

2.2.1 Processor survey

A mini survey was conducted using a rapid appraisal method to carry out a formative evaluation of the current state of the processors' knowledge, attitudes, and practices. Semi-structured, one-on-one interviews combined with on-site observations were conducted for twenty-six (26) cheese processors who were selected using non-probability sampling. Processors were selected from cattle rearing villages in Southern Ghana (Table 2.1), where considerable cheese processing activity occurs. Due to surges of covid-19 in Ghana and the restriction of movement in parts of the country during the study, efforts were made to choose a representative sample in any given location as shown in table 2.1. In addition, non-participating producers in the locations visited had similar assets and processing protocols, received milk from the same kraals and retailed to similar markets. The specific cheese type is locally known as *Wagashie*.

Table 2.1: Study locations in Ghana

Processor Locations	Description	District	Administrative region	Number of processors counted	% Included in study
Aveyime-Battor	Rural	North Tongu	Volta	15	73
Akuse	Rural	LowerManya Krobo	Eastern	7	70
Agomeda	Rural	Dangbe West	Eastern	3	100
Dodowa	Peri-urban	Shai Osudoku	Greater Accra	2	100
Sasaabi	Peri-urban	Shai Osudoku	Greater Accra	1	100
Tulaku	Low-income urban	Kpong Katamanso	Greater Accra	2	100

The main objective was to capture the respondents' knowledge on food safety and hygiene practices during traditional cheese processing, their attitudes towards incorporating such behavior in their operations, and their practices during regular operations from raw material through retail. The hypothesis was that all traditional cheese processors have poor food safety and hygiene

knowledge, attitudes, and practices. The interviews were also meant to help identify challenges faced by processors, assess the influence of supply chain factors, if any, and establish reference values for an educational intervention. Interviewees were given a brief background on the subject, and consent was sought prior to interviewing and observing their processing activities. The semi-structured questionnaire was developed using the Code of Hygiene practice for milk and milk products (Food and Agricultural Organization, 2009) and reference material from the Ghana Code of Hygienic Practices and the SSAFE Global Dairy Farming Food Safety Training framework. SSAFE is a global non-profit membership organization that works to strengthen food safety and improve human, plant and animal health and well-being. The interview covered demographics, a description of the processing environment, process controls, and the processors' opinions on processing, hygiene, and food safety. To be included in the study, cheese processors who consented to the study were required to meet the following criteria: be uncertified by the Ghana Food and Drugs Authority; live and conduct processing activities in the study area; have no accredited or formal food hygiene training and operate on a micro to small scale according to definitions by the Ghana Statistical Service.

2.2.2 Scoring

Using a scoring system, answers for knowledge were scored one point for correct answers and zero for wrong answers or if respondents answered no/do not know. Attitudes were ranked based on three score levels; agree (two points), neutral (one point) or disagree (zero points). Practices were self-reported answers to open-ended questions and compared to observations. The answers given were coded based on whether they were a best practice (two points), good/acceptable practice (one point) or a poor practice (zero points). The coded practices were further ranked based on the rate at which they were practiced spanning from always (two points),

sometimes (one point), to never (zero points). Multiplication of the codes with the ranks gave a final score that was recorded as the respondent's practice score for a question (Example: If a respondent's particular practice was best (two points) and they always (two points) carried this out, then their score for that practice would be four (4). The total practice score was then calculated for each participant. The higher the scores, the better the respondents' knowledge, attitudes, and practices were assumed to be towards food safety and hygiene. Using Bloom's cut-off points, if the total percentage of correct knowledge answers or the percentage of desired or positive attitudes, or the percentage of optimal practices was less than 60%, the respondent was at considerable risk for food safety issues. They were considered a medium risk for scores between 60% and 79%. For scores above 80%, they were considered a minimal risk (Table 2.2).

Table 2.2: Score Classifications

Total Knowledge Score	Total Attitude Score	Total Practice Score	Score (%)	Level
11 – 13	16 -20	16+	80 - 100	Good
8 – 10	12 -15	12-15	60- 79	Average
<8	<12	<12	< 60	Poor

2.2.3 Statistical analysis

Descriptive statistics (mean, median, range, frequencies, and percentages) analyzed quantitative and categorical variables. Open-ended answers were analyzed in MS-Excel by creating sub-categories and calculating frequencies for repeating themes. Cross tabulations, the Fisher Exact test (for nominal data) and Mann-Whitney U test (for ordinal data and nominal data comparisons) were conducted using SPSS version 25 to test associations between demographic variables, processor characteristics and the association among knowledge, attitudes, and practices.

2.3 RESULTS AND DISCUSSION

2.3.1 Processor Characteristics

Tables 2.3 and 2.4 below show demographic information and other processor characteristics. Twenty-six (26) female processors were interviewed. The majority (50%) of the respondents were less than 31 years old. The majority were multilingual, with Fula as their primary language but could also fluently speak and understand other Ghanaian languages, specifically Hausa, Dangbe, Ewe, Twi, Ga, and English. Most participants lived and operated in areas classified as rural, and the majority (90%) had not received any formal education.

Table 2.3: Demographic characteristics of cheese processors (n=26)

Demographic variable	Status	(%)
Age distribution	18 -30y	50.00
	31-50y	30.77
	51y +	19.23
Language	Multilingual	76.92
	Fula (primary)	
	Multilingual	15.38
	Other(primary)	
Location	Unilingual	7.69
	Rural	65.38
	Peri-urban	11.50
Education	Urban (low income)	26.92
	None	69.23
	Primary School	19.20
	Secondary School	13.04

Table 2.4: Processor characteristics (n=26)

Processor Characteristic	Status	(%)
Occupation	Cheese only	61.54
	Cheese & other agricultural activity	11.54
	Cheese & other food service activity	23.08
Training type	Informal via predecessor	100
Operation type	Self-owned	92.30
	Apprentice	7.69
Retail mode	Informal market & wholesale distributor	76.92
	Informal market & wholesale distributor & other	23.07
Health certificate	Yes	11.53
	No	88.47
Smartphone	Yes	53.84
	No	46.16
Electricity	Yes	69.23
	No	30.77

Although the study was targeted at cheese (*Wagashie*) processors, the minority of the respondents also engaged part -time in other agricultural activities like vegetable farming and cattle rearing and food service activities. All respondents reported not seeking any formal training for cheese making; most of their skills came from adult family members who were or had been cheese processors. While most processors owned their operations, their primary role in the supply chain was to distribute wholesale quantities of fresh cheese to retailers and other foodservice actors in informal markets for further processing into other forms (smoked/fried *Wagashie*). Very few processors doubled as wholesale distributors and retailers, but the products were sold fresh in such cases.

Many cheese processors did not have a government -approved health certificate often mandated for food handlers. The few who did had acquired them for other foodservice activities

and not cheese processing. Many of the processors also had full access to working smartphones and electricity.

2.3.2 Description of the processing environment

The cheese type processed, locally known as *Wagashie*, can be described as a soft, fresh unripened cheese made from whole milk. Cheese (*Wagashie*) was often processed in an enclosed and poorly ventilated area. A simple structure usually made from wood, thatched roofs, and sandy floors was often designated solely for cheese processing (Figure 2.1). Most processing areas had no windows. Firewood, the primary fuel source, was stored inside the processing area in many instances. Most processing areas were in close vicinity to cattle kraal. Some processing areas were shared with farm animals. In these cases, some sort of barrier was mounted to prevent animals from freely walking into the processing space while it was in operation. Aluminum pots were the main utensil for preparing the cheese. *Calotropis procera*, the plant from which the coagulant was extracted, was sourced locally from the neighborhood. The coagulant was extracted by pounding in wooden mortars with a wooden pestle. The straining and molding of the cheese (*Wagashie*) curds was done with wooden baskets. In very few instances, plastic molds were used. The process flow is described in Figure 2.2.



Figure 2.1: Interior and exterior views of typical processing areas; molding baskets for *Wagashie*

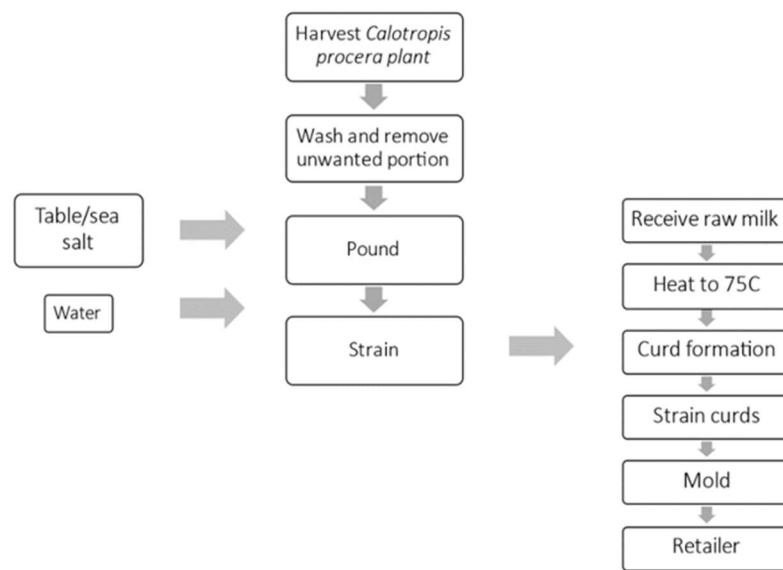


Figure 2.2: Flow diagram of the *Wagashie* making method as reported

All the processors used salt and *Calotropis procera* stem (coagulant source) as the only other ingredients apart from whole raw milk for making *Wagashie*. They all knew the purpose of *Calotropis procera*, but many could not explain the function of the salt. *Calotropis procera* plants

were uprooted from the immediate vicinity to isolate the coagulant of interest. The leaves were removed, and the stem was cut up into pieces. Depending on the quantity of milk, an appropriate amount of cut stem was pounded using a wooden mortar and pestle. The average quantity observed was to use 0.5 meters of stem for about twenty-five liters of fresh milk. The pounded mash was mixed with about a cup or two of water and, in rare instances, milk. The resulting solution was strained directly into a large cooking pot containing cheese milk during the cheese making process. All measurements were done according to each processor's knowledge. Measurements conducted on-site revealed that the average pH of the milk was 6.7 before the addition of the coagulant and 6.3 after curd formation began. The average temperature at which curd formation began was 75°C. After the curds were formed, they were drained and flipped a couple of times to attain the final form. After this step, no further treatment was given, and the curds were distributed. Some distribution practices included leaving the curd in whey until they reached the next point in the supply chain or keeping them in cool water to prevent them from sticking to each other. Only one (1) processor mentioned sun-drying the curds to reduce the moisture content, but this was not directly observed.

2.3.3 Knowledge

Three broad indicators were used to assess participants' knowledge. These were hazards and process controls, sanitation, supply chain or other controls. A total of thirteen (13) questions with close-ended choices were presented to processors. These questions were selected to suit their operational mode and levels. Table 2.5 shows the percentages of the responses that were recorded.

Table 2.5: Knowledge responses from cheese processors

	n (%)			
	Reported		Observed	
	Yes	No*	Yes	No
Hazards and process controls				
It is important to be familiar with common hazards associated with cheese processing	20 (76.92)	6 (23.08)		
The temperature of received milk must be measured as an indication of quality	0 (0.00)	26 (100.00)		
Received milk and other raw materials must be inspected for hazards and contaminants before use	26 (100.00)	0 (0.00)		
Curd boiling and straining must be controlled to prevent product defects	26 (100.00)	0 (0.00)		
Temperature control after cheese processing is critical for quality and safety	0 (0.00)	26 (100.00)		
Sanitation				
The sanitation of my processing environment can influence the quality of cheese	9 (34.61)	17 (65.38)	26 (100.00)	0 (0.00)
Before and after processing, I must clean my processing area and equipment	26 (100.00)	0(0.00)	26 (100.00)	0 (0.00)
During processing I must wear clean clothes and cover my hair	7 (26.92)	19 (73.08)	0 (0.00)	26 (100.00)
During processing I must wash my hands if I leave the area or touch another human being or object or use the toilet	14 (53.85)	12 (46.15)	0 (0.00)	26 (100.00)
I must avoid processing when I am sick with a communicable disease	8 (30.77)	18 (69.23)		
During processing I must immediately remove hazards and adulterants when observed	22 (84.62)	4 (15.38)	9 (34.61)	17 (65.39)
Supply chain and other controls				
I should be aware of the types and signs of defects and spoilage that can occur with my products	26 (100.00)	0 (0.00)		
It is important to give specifications to raw material suppliers	0 (0.00)	26 (100.00)		

*Answers “No” include “Don’t know.”

Most processors (>70%) reported that processing steps, such as inspecting raw materials before processing and controlling the boiling process, were critical to product quality. The majority also expressed that it was necessary as a processor to be familiar with hazards associated with cheese processing. However, none of the processors agreed that the temperature of the received milk was an indication of its quality.

Sanitation was directly observed and compared to the responses given by the processors. All the processors mentioned that it was essential to clean the area and equipment before and after processing, and they all complied, but the cleaning method was more thorough for some processors than others. More than 80% agreed that adulterants and hazards must be removed immediately when sighted during processing, but only about 40% performed these actions. All the processors were working under unsanitary environmental conditions that were likely to affect the product quality; however, less than 40% attested that this was true. The majority response to whether you must wash your hands when you leave the processing area for any reason was yes; however, none of the processors were observed performing this action. Among processors who responded no to the same question, the explanation was that cheese processing involved critical techniques, so it was better not to leave the processing area for any reason. Critical techniques in this instance referred to keenly observing the changes in cheese milk as soon as processing began to help regulate the heat source and prevent product defects. Most of the processors (73%) did not recognize the need to wear clean clothes or cover their hair during processing. While it was observed that none of the processors had clothing that was dedicated to processing, all of them had hair covering in the form of scarves, turbans, or hijabs. Culturally, it is normal for some African and Muslim women to cover their hair during daily activities and outside the privacy of their homes. All the processors agreed that knowing about defects and causes of spoilage in cheese was critical; however, all the processors felt it was not in their place to provide specifications to their respective raw material suppliers. For most processors, the milk came from family farms and relatives. Others were supplied from neighborhood milk farms. None of them believed that what happened to the raw material before it got to them was a concern.

An open-ended question asking what conditions processors thought affected product quality, especially since the majority (65%) did not believe that environmental hygiene was a determining factor, yielded diverse responses (Table 2.5). Among the extrinsic factors, several of them listed changes in milk texture due to seasonal changes, with the rainy season bringing superior quality milk that was thicker and creamier. Others pointed to farming factors like cow feeding practices and whether the cow had calves that were lactating or not. The point on lactation was not milk quality but the quantity they would receive since they (processors) will compete with the calves for milk. Among the intrinsic factors, many mentioned that how well the cheese was cooked would determine the keeping quality. They explained that perfectly cooked cheese would have a firm curd that does not spoil quickly. The intensity of fire used was also pointed out. The explanation was that using high heat after adding the coagulant will produce weak curds or other product defects. Other factors that were commonly mentioned were the type of coagulant used. Most processors reported that using the stem of the *Calotropis* plant instead of the leaf gave better yield and a better-quality product. Some claimed the leaf caused color changes and bitterness. Some processors also mentioned that how long milk was kept before processing will affect the product quality; the longer it stays, the higher the defects. Such defects included total product failure. Upon asking how best the product could be kept, many processors responded that cooking the product well or boiling it in hot water on subsequent days was enough to make the product last between three and fourteen days (about two weeks) without refrigeration.

Overall, it was discovered that none of the participants had good knowledge about safety and hygiene during cheese processing. Very few had average knowledge, but the majority had poor knowledge of what was expected of them as processors (Figure 2.3).

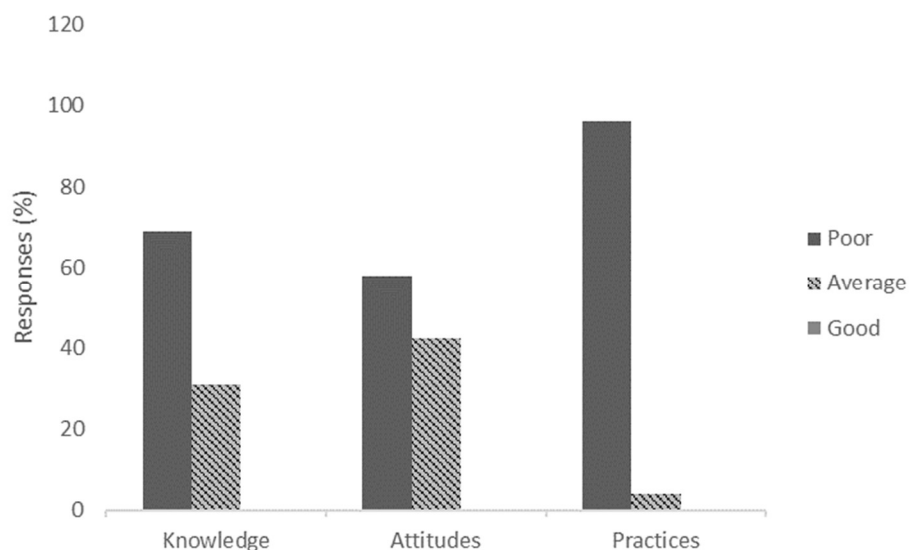


Figure 2.3: Total knowledge, attitudes and practices ranks for traditional cheese processors

2.3.4 Attitudes

When the respondents were asked about their attitudes concerning processing, sanitation, and hygienic practices, overall, most of them had poor/incorrect beliefs (Figure 2.3). All the processors believed that having some food safety plan and receiving training on hygiene and sanitation was important. The majority (80%) believed that knowing about food safety hazards, implementing controls for traditional processing, and knowing about product defects were important. Processors were asked if they believed they had to give suppliers and retailers certain specifications for how raw material or finished products may be handled to improve quality. Unfortunately, none of the processors believed that this was in their place to do. The majority (92%) also disagreed that a cold chain would enhance the shelf life of their products and that product quality was influenced by personal hygienic practices or the hygiene of the environment (Table 2.6).

Table 2.6: Attitudes towards food safety and hygiene

Statements	Agree	n (%)	
		Disagree	Neutral
I believe that knowing about hazards is important	21 (80.77)	0 (0.00)	5 (19.23)
I believe that process controls can be implemented for traditional dairy products	21 (80.77)	1 (3.85)	4 (15.38)
I believe that suppliers and retailers must follow specifications to maintain product quality	0 (0.00)	26 (100.00)	0 (0.00)
I believe that training is important for traditional processors	26 (100)	0 (0.00)	0 (0.00)
I believe that processors must be concerned about product defects	20 (76.92)	0 (0.00)	6 (23.08)
I believe that if one product is defective or adulterated, the entire batch must be thrown out or reworked	0 (0.00)	14 (53.85)	12 (46.15)
I believe that maintaining a cold chain is important to extend shelf life	0 (0.00)	24 (92.31)	2 (7.69)
I believe that hygienic practices and environmental hygiene influence product quality	9 (34.62)	13 (50.00)	4 (15.38)
I believe that food safety plans will help with meeting standards	26 (100.00)	0 (0.00)	0 (0.00)
I believe that a food safety plan will help sell beyond informal markets	0 (0.00)	0 (0.00)	26 (100.00)

Many processors did not believe that their products were unsafe and unsanitary and attributed this to their products being well cooked or sold fresh. When asked if they felt that consumers perceived their products were unsafe and unsanitary, there were divided answers. Most of them said they would understand if some felt that way because they believe that many of them do not know how the cheese was processed, and many processors and retailers work in unsanitary conditions. A few other processors said that they believed consumers looked out for visual cues like color, shape, and size of the product before buying and were therefore not genuinely concerned about sanitation. Upon asking if they believed that the traditional cheese products were better than modern ones, the consensus was yes because they believed traditional products were tastier, healthier, more nutritious and did not contain artificial additives. Many also attested they had never seen or tried modern cheese products but felt their products were better. When asked if they believed that they could sell their products in formal markets like supermarkets and gas stations if

their food safety and hygiene knowledge were improved, they were all neutral, with some reluctantly saying that it was possible. While some expressed that they did not know if their products had a place in the formal marketing outlets, others were nonchalant with the simple explanation that they had never tried and would not know. Some said they had never ventured outside what they knew, and others expressed that it might be an avenue for a better price. A few, however, expressed doubt that traditional cheese had a place in formal marketing outlets.

2.3.5 Practices

Answers for practices were both self-reported and confirmed with observations. There were no differences between self-reported answers and observations made on site. All processors conducted some form of screening for raw milk prior to processing. Most (92%) reported straining the milk to remove residual dirt, hair, and other particles. Very few reported tastings or smelling the milk or using other physical characteristics to determine if it was sound for processing. None of them used milk that had undergone microbial or physicochemical testing. All processors processed milk within an hour after receipt, insisting that it was best to begin immediately the milk arrived. Most reported that the milk would either go bad or not form cheese curds if kept for extended periods prior to processing.

Since the cheese making process requires careful temperature regulation, it was essential to assess how this is done. In the absence of specific temperature measuring tools, most processors resorted to visual cues to indicate when the heat source should be regulated to aid the curd formation process. While most (88%) of the processors relied on their experience, many of them confirmed by dipping their fingers directly into the pot to check the temperature of the milk. A couple of them reported taking a small sample out of the pot to check the temperature. Upon completing the process, the processors gave no further treatment to cheese. Again, many

processors did not feel it was essential to tell retailers or consumers how to safely handle or consume the products. Very few of them recommended refrigeration as a preservation option, but many said they felt that people already knew how to handle the product.

Most processors also produced cheese for immediate and external retailers, suppliers, and consumers. The mode of transportation was often via head porters or motorbikes. Very rarely, processors use public transportation modes like commercial buses to deliver products.

Table 2.7: Self-reported and observed practices of processors ranked as poor, good, or best

Self-Reported Practices	rank	n (%)
Milk handling		
Strain	good	24 (92.31)
Visual exam	good	1 (3.85)
Taste and smell	good	1 (3.85)
Length of time milk is kept prior to processing		
Process immediately milk arrives	best	26 (100)
How to properly regulate cooking temperature		
Observe physical signs and dip hand in cooking cheese	poor	23 (88.46)
Observe without hand dipping	good	2 (7.69)
Fetch sample and dip finger	good	1 (3.85)
Treatment given to the finished product		
Drain for 3 minutes and distribute	poor	26 (100)
Instructions given for handling and consumption		
None	poor	23 (88.46)
Refrigerate	best	2 (7.69)
Will provide when asked	poor	1(3.85)

2.3.6 The relationship between processor characteristics and knowledge, attitudes and practices

A key finding of this study was that most cheese processors receive all prior knowledge regarding processing cheese from predecessors in their family only. Therefore, knowledge about hazards and process controls, sanitation, and supply chain controls on the impact of safe and hygienic processing is limited and, in some cases, inaccurate. For instance, most expressed the view that the milk came directly from dairy farms primarily within, and sometimes external to, their processing vicinity, and they had never considered measuring the temperature of the milk they received. For those who lived near kraals, milk delivery was often done by male family members or neighbors who tended to the cows. For milk received from the immediate vicinity, it was often transported in plastic gallons and buckets on foot or motorcycles. There were also no measures to ensure milk was cooled via transportation. While milk remains sterile in the udder, it is essential to note that the storage temperature after milking plays a considerable role in the microbial proliferation of microorganisms of public health significance and the risk of illness (Crotta, et al. 2016; Raza & Kim, 2018). The code of hygienic products for milk and milk products (CAC/RCP 57-2004) also recommends that harvested milk must be cooled and maintained at a temperature that ensures that microbial growth is limited.

In terms of sanitation controls, most processors lacked the knowledge that wearing clean clothes, hand washing, and processing in a clean environment could directly affect product quality outcomes. Observations revealed that many processors removed adulterants without much thought to re-contaminating the products at other processing steps or not correcting their actions, even after reporting they did. Corrections observed included directly dipping dirty fingers into milk to remove particles and directly picking particles out of cheese curds with unclean hands. According

to Owusu-Kwarteng, et al. (2020), during traditional milk processing, the poor sanitation of the processing environment and poor personal hygiene of the processors can cause direct contamination of processed products with pathogenic microorganisms. A comparative study conducted by Schoder, et al. (2013) on the hygiene of products from milk processors in Tanzania revealed that processing under unhygienic conditions was merely due to no understanding of hygiene and no motivation to maintain hygienic conditions. This lack of knowledge was further positively correlated with the subsequent discovery of higher-than-normal counts for total bacteria counts, Coliforms and *Escherichia coli* in many samples from processing plants where poor worker hygiene was prevalent.

Another important finding of this study was that, although cheese processors are not the endpoint in the local cheese supply chain, they did not know that providing specifications to actors upstream and downstream could play a role in product quality. Analysis of dairy supply chain features likely to create unsafe supply in Pakistan by Hassan et al. (2021) revealed that safety failure factors could be because of farm -related or retailer-related factors such as inadequate health conditions of farmers, mediocre quality controls in milk production, unhygienic transportation of dairy products to retail and the subsequent sale of unsafe products. A preliminary analysis on smallholder dairy production in Indonesia by Daud, et al. (2015) also showed that milk handling and transportation practices constitute a chunk of risks of varying nature in the supply chain. There are not enough safety features in place for smallholder operations, or in this context for the actors, to present risk-minimizing behavior to ensure safe supply to downstream actors.

Table 2.8 below shows some analytical data measured during processing as indicators of microbial survival. Despite the risk-enhancing behaviors discussed in this study, raw milk at reception was within acceptable pH limits. Milk was further boiled to temperatures higher than

legally recommended pasteurization temperatures. At the end of production, the temperature of *Wagashie* cheese could still permit the survival of bacterial spore formers however heat resistance is highly dependent on the optimum pH for their survival (USFDA, 2009). It must be noted that the limited scope of the study did not consider other risk factors during milk harvesting and retail.

Table 2.8: Inferential analytical parameters for indices of possible microbial survival

Process variable	Location	Inferential analytical parameter accessed		Reference values for microbial survival	Reference
		pH	Temperature		
Milk reception	Ab	6.7 ± 0.0		< 6.5-6.8	Marouf & Elmhal, 2017; Gwandu et al, 2018; EAS 67, 2006
	Ak	6.5 ± 0.2			
	Ag	6.8 ± 0.2			
	Do	6.8 ± 0.1			
	Sa	6.7 ± 0.0			
	Tu	6.4 ± 0.1			
Initial heating of milk (10 mins)	Ab		70 °C ± 5 °C	< 69°C for 30 mins (Vat pasteurization)	IDFA, 2022
	Ak		75 °C ± 5 °C		
	Ag		82 °C ± 5 °C		
	Do		75 °C ± 5 °C		
	Sa		75 °C ± 5 °C		
	Tu		78 °C ± 5 °C		
20 minutes into cooking process	Ab	6.5 ± 0.0	90 °C ± 10 °C	< 69°C for 30 mins (Vat pasteurization)	IDFA, 2022
	Ak	6.3 ± 0.2	85 °C ± 7 °C		
	Ag	6.2 ± 0.2	90 °C ± 5 °C		
	Do	6.2 ± 0.1	90 °C ± 8 °C		
	Sa	6.5 ± 0.0	85 °C ± 10 °C		
	Tu	6.2 ± 0.1	85 °C ± 5 °C		
End of process (Final product)	Ab	6.71 ± 0.03	80 °C ± 5 °C	pH~ 5.5 - 7	Anihouvi & Kesenkas, 2022; Aboudoulaye & Kaya, 2020
	Ak	6.69 ± 0.10	75 °C ± 3 °C		
	Ag	6.70 ± 0.00	82 °C ± 5 °C		
	Do	6.50 ± 0.00	83 °C ± 8 °C		
	Sa	6.71 ± 0.02	75 °C ± 5 °C		
	Tu	6.50 ± 0.00	82 °C ± 5 °C		

Ab – Aveyime-Battor, Ak – Akuse, Ag – Agomeda, Do – Dodowa, Sa – Sasaabi, Tu - Tulaku

A positive outcome of this study was that most of the processors agreed that specific interventions were necessary. These included the need for training, having a food safety plan, improving controls in traditional processing and being familiar with common hazards and product

defects. However, an overall analysis of all questions revealed that attitudes towards food safety and hygiene were not optimal for all processors. A chunk of the suboptimal attitudes was remarkably like knowledge analysis, giving specifications to retailers, hygienic practices, and environmental conditions. An interesting finding was the processors' negative attitudes towards the role a cold chain may play in cheese quality. Notably, while some of the processors had access to electricity, they had all learned processing from people who had no access to electricity. Therefore, a cold chain was not a factor to consider during operations. It is also highlighted that no temperature control was involved for raw products (milk) or the finished product (cheese). While soft unripened cheese also presents a high-risk factor for microbial growth, we must remember that this factor was also of little concern because the processors were not the endpoint in the supply chain.

Location type did not influence processor attitudes. This result was likely because the interviewed processors lived in low-income areas and had the same operational and marketing strategy through informal markets. Informal markets usually have lower standards and poor regulation, so requirements for quality are not as enhanced (Staal, et al. 2008). It is also worth noting that the consumer type has long driven the marketing trends in sub-Saharan Africa (Aschemann-Witzel, et al., 2021; Walshe, et al., 1991) and therefore, the considerations that processors will be willing to put in place to improve hygiene and safety perceptions. Other indicators of socio-economic status of the processors, such as whether they had a health certificate, electricity, or a smartphone or not, did not influence their attitudes either. Age group and education status, however, were positively correlated with attitudes. In assessing the influence of the attitudes and behavior of milkers, in the Antioquia province of Colombia, on the sanitary quality of milk, Múnica-Bedoya, et al. (2017) found that the presence of learning opportunities and younger ages

of milkers were among factors that were positively correlated with excellent hygienic and sanitary parameters of milk. Another study conducted by Paraffin, et al. (2018), for both small- and large-scale dairy farmers in Zimbabwe revealed that age affected the perception of quality, as farmers older than 30 years were more likely to understand that hygiene will influence milk quality.

There was not enough statistical evidence to suggest correlations between any of the processor characteristics and self-reported practices. The study, however, revealed that all processors were engaged in at least one best practice where received milk was not stored for longer than an hour prior to processing. This practice was gained solely through experience because many processors explained that several things could go wrong if milk was stored. Among these were milk spoilage, low yield, and product failure. A training program for the small -scale dairy sector in Kenya by the FAO (Food and Agricultural Organization) recommended that milk be transported fast, efficiently and processed quickly to reduce the potential for microbial growth.

Prior to processing, the processors reported and were observed in many instances straining the milk to get rid of physical hazards like animal hair, houseflies, and other debris. While this is good practice, other well-established tests for milk quality were absent. Many explained that the milk was received fresh from the kraal, and therefore, there was little possibility that the milk would go bad. The milk was not received via cooperatives or commingled milk sources where they may have undergone bacteriological testing. Processors did not report conducting any physicochemical tests on the milk received to ensure it was adequate for processing either. Even basic organoleptic tests like observing the color, smell and taste were not conducted.

2.3.7 Factors that affect cheese quality according to traditional cheese processors

The findings of this study uncovered that, regardless of the status of knowledge, attitudes, and practices regarding food safety and hygiene during processing, traditional cheese processors

were knowledgeable on internal and external processing conditions that may affect product quality, contrary to popular opinion. The open-ended question, “What affects the quality of *Wagashie* (cheese)” allowed processors to express diverse views on what they knew, believed, and practiced (Table 2.9).

Table 2.9: Processing and non-processing factors that affect cheese quality according to traditional processors

Processing related factors	Perceived consequences
Keeping milk longer than 4-6 hrs. prior to processing	Product failure
Re-constituting raw milk with powdered milk	Weakens the cheese curd
Poor regulation of heat	General product defects
The use of <i>Calotropis</i> leaves instead of stem	Causes bitterness
Cooking thoroughly	Strengthens cheese curd
Refrigeration	Disintegrates cheese curd
Excessive salt	Decreases yield
Re-boiling as a preservation method	Curds shrink in size, but increase in density
Non- processing -related factors	Perceived consequences
Season	Variations in season change milk quality
Lactating cows (early stage)	Poor milk quality
Poorly fed cows	Poor milk quality
Distance from farm to the processing site	Delaying milk arrival changes taste

Processors explained what processing factors they believed would influence the quality of cheese. Among them was the regulation of heat. Temperature regulation during the cooking process is a critical step, the lack of which will lead to critical product defects like poor curd formation or total product failure. The method of dipping a finger directly into cooking cheese, as practiced, could be a source of contaminants. However, it is worthy to note in the book, *Life of Cheese*, Paxson (2013) details how traditional American cheese makers have similarly drawn on past experiences and generational knowledge, and in the absence of modern equipment, trusting hands over thermometers successfully crafted some of consumers' most -loved cheese. “*When the*

cheese is ready for reduced fire, I can tell by just looking at it. Some water collects on the surface” (Processor Interview).

Processors also highlighted other factors contributing to product defects and total product failure. Among them included keeping the milk for longer than a minimum of four (4) hours before processing. Some processors explained how this would lead to yogurt production instead of cheese. *“If you leave the milk standing, the product will become yogurt, not cheese”* (Processor Interview). Because fresh milk is an optimum medium for microbial growth, it is common for spontaneous fermentation to occur. Indeed, spontaneous fermentation is harnessed in the production of yogurt-type traditional dairy products. Research has shown the involvement of species from the *Lactobacillus*, *Lactococcus*, *Acetobacter*, *Streptococcus* genera and some yeast and mold are often involved in these fermentation processes (Akabanda, et al., 2014; Groenenboom et al., 2019; Nduko, et al., 2017).

Regarding curd integrity, processors mentioned factors such as the non-traditional addition of milk powder, thoroughly cooking the curd and refrigeration of the final product. More standardized cheeses often have well-documented process control points that cater to the concerns raised. Although there is no literature citing the investigation of these factors on curd integrity of this specific fresh unripened cheese type, investigations have been carried out in other cheese categories with varying results. For example, Rehman, et al., (2003) successfully used whole milk standardized with dry milk protein concentrates to produce reduced-fat cheddar cheese. This technique successfully increased the total solids content while reducing whey volume, alluding to the increased firmness of the cheese curds. In industrial settings, physicochemical indices like titratable acidity (TA) and pH monitor the cheese cooking process. Hill and Ferrer (2021) note that TA will often vary with milk composition, while pH indicates acid development throughout

the cheese making process and can be used to control pathogenic and spoilage microbes. On the contrary, in smallholder non-formal settings, the technical knowhow is often absent (Lindhahl, et al., 2018; Omore et al., 2009).

Another important finding of the survey was how the final product is handled after processing before it goes to the next actor in the supply chain (usually retailers or food services). Observations included allowing cheese curds to form and drain in perforated cane basket molds for a maximum of three (3) minutes, during which there is a quick flip, and then the cheese is allowed to sit in a bowl while the excess whey pooled around it. There was no indication of how long cheese remained in that condition during transportation. However, re-introducing moisture after attempting to drain the product may or may not affect the cheese's physicochemical properties. This possibility is being investigated in subsequent studies.

Non-processing -related factors that processors believed could influence cheese quality were related to season, some animal farming practices and the distance from the farm to the processing site. Processors explained that season and animal rearing practices often affected the creaminess of the milk and, therefore, the yield. Specifically, they received more watery milk during the dry season and when an animal had younger calves. Changes in milk composition during seasonal and gestational -related changes are well documented in the literature (Gillah, et al., 2014; Li, et al., 2019; Lin, et al., 2017; Roessler, et al., 2019). However, processors also showed concern in changes to the taste of fresh milk received if the distance from the farm was too far or a delay in transporting the milk to the processing site occurred due to uncontrollable factors like poor weather, unavailable transportation, or other factors. In such cases, the milk was still used, but the possibility of product failure was high, as previously explained.

Table 2.10: P-values from Fisher's exact test

Processor Characteristic	Knowledge	Attitudes	Practices
Age group	0.164	0.004	0.595
Education status	0.064*	0.035*	0.512*
Location type	0.185	0.339	0.244
Health certificate	0.220	0.364	0.713
Electricity	0.671	0.597	0.497
Smartphone	0.149	0.391	0.345

*Numbers are significant at $p < 0.05$. *Performed by Man Whitney U test*

Table 2.11: Pearson's correlation among knowledge, attitudes, and practices (p-values)

	Attitude	Practices
Knowledge	< 0.001	0.126
Attitude		0.234

There is a statistically significant association if $p < 0.05$

2.4 CONCLUSIONS

Overall, this study confirmed the hypothesis. The results showed that most of the cheese processors in Southern Ghana who were interviewed had poor knowledge, attitudes and practices regarding food safety and hygiene during traditional cheese processing. Specifically, the processors lacked knowledge in setting up the processing area; sanitation protocols before, during and after processing; Process controls that may prevent the introduction of adulterants and enhance overall product quality; Temperature control after processing. They also had poor attitudes regarding specifications for supply and retail, the influence of the production environment on product quality, and expanding their market reach. Best practices that could be improved include inspecting all raw material before processing, regulating cooking temperature during processing, better handling finished cheese curds, and improved preparation for transportation. There was some statistical evidence to suggest an association between age and education status with attitudes. There was, however, not enough evidence to suggest that there was an association between any other demographic or processor characteristics and either knowledge, attitudes, or practices. Overall, there was no correlation between practices and attitudes or knowledge. Attitudes and knowledge, however, were associated.

Processors agreed that training is needed to increase their ' knowledge, attitudes, and practices. Although several training programs exist, these processors do not have access to technical information. There is the need to create a training program suited to their level of understanding and needs.

In addition, since the product moves to another actor in the supply chain, there is a need to investigate appropriate processing and post-processing techniques to reduce whey pooling while maintaining pH in the absence of cold storage. This technique is vital to minimize the potential for recontamination and spoilage. The technique may also be more cost-effective to processors who

reported having to boil remaining pieces of cheese daily and ensure that retailers receive a safe product. Such procedures can be introduced to the traditional processors to gauge their feasibility.

**CHAPTER THREE: THE COMBINED EFFECT OF CURD COOKING TIME AND
SALT CONCENTRATION ON THE PHYSICOCHEMICAL COMPOSITION OF
UNRIPENED FRESH CHEESE CURDS**

3.1 INTRODUCTION

Wagashie is a traditional type of fresh unripened cheese that is popular in the West African region. It is made by coagulating boiled whole cow's milk using extracts from the leaves and stems of a local plant, *Calotropis procera* (Sodom apple) that has been reported to contain rennet enzymes (Chikpah et al, 2014). According to Omore et al. (2009) during traditional processing, received milk is usually processed within four hours after an optional visual non-standardized inspection. The milk is boiled, mimicking pasteurization, and the coagulant (*Calotropis procera*) is processed separately and added. The added amount of coagulant varies from processor to processor. Some processors add a reddish dye extracted from sorghum sheath for aesthetics and preservation. Very few processors add salt during milk coagulation in low concentrations, but this is not a regular practice. After coagulation, milk curds are allowed to drain to remove excess whey for a limited amount of time in order to regain structure. The product has a high moisture content, and as such, it is highly perishable with its shelf life not exceeding three days (Tohibu et al, 2013). The size of the resultant cheese depends on the size of the mold used (O'Connor, 1993) or how it is cut after hardening. The process does not involve the inclusion of starter culture in its preparation (Ashaye et al, 2006). It is consumed as a meat or fish alternative in the diet and is usually boiled, poached, fried, or smoked.

During *Wagashie* processing, heat is used at temperatures of 65- 75°C as a medium to transform liquid milk into a solid mass curd. Classical studies by Magee and Harvey (1926) showed that heat potentially increases the volume of casein in fresh milk, and therefore contributes to coagulum formation. Heated milk may also react differently with rennet by showing an increased coagulation time (Mattick and Hallet, 1929). This suggests that heated milk is prepared for coagulation with *C. procera* extracts. Although *C. procera* stems and leaves undergo minor

processing before it is added to hot milk, the enzyme of relevance is activated at high temperatures while potential toxins are simultaneously inactivated (Baba-Moussa et al, 2007; Oseni & Ekperigin, 2013). With reference to O'Connor (1993), the process of heating may also cause the formation and possible loss of coagulated fats and proteins on the surface. Kethireddipalli and Hill (2015) suggest that thermal processing may be detrimental to the rennetability of rennet coagulated cheese since whey proteins are lost during processing.

The resulting gel structure of renneted curds is often affected by several physicochemical factors including temperature and moisture content (Giroux et al, 2014; Marshall, 1982). The final color of the product may be influenced by the burning of milk solids if stirring is not done consistently. Yield and texture may be affected by the type and quantity of coagulant, and the use or omission of starter cultures. According to O'Connor (1993), starter cultures are often not readily available or too expensive for smallholders, and as a result, acid production during *Wagashie* production will occur due to inoculation with whey from a previous batch, or by naturally occurring microorganisms.

According to Guinee and Sutherland, (2022), salt in cheese is important for not only its perseverative and flavor enhancing effects, but also its role in the proteolytic activity of residual coagulants on casein in high moisture systems. In conjunction with pH and calcium, it may also influence hydration and aggregation of para-caseins, influencing key structural indicators such as syneresis, rheology and texture. The addition of NaCl to some cheese types has been shown to increase syneresis while decreasing the moisture content by hydrating and expanding the protein matrix (Pastorino et al, 2003).

Syneresis describes the expulsion of whey from cheese curds during cooking. It may or may not be desirable depending on the type of cheese. Most ripened cheeses are low moisture

types and therefore whey expulsion techniques like curd cutting, stirring, and salting are employed to extract moisture from cheese curds during cooking. For unripened fresh cheeses with a high moisture content, it may be desirable to improve the moisture content of the curd using techniques that may not disrupt the cheese matrix during cooking.

To determine what factors affect the physicochemical composition of *Wagashie* when made by simulating the traditional processing method, the effects of length of exposure of renneted curds to heat during processing and salt content will be studied. It is hypothesized that; the combination of long-time heat exposure and increased salt will improve curd composition and possibly integrity.

3.2 METHODS

3.2.1 Experimental design

Two experimental factors were considered for this study; salt content and curd cooking time after rennet addition. During observational studies for traditional processing of *Wagashie*, it was recorded that the quantity of salt added to the coagulant was approximately 6g (half a tablespoon) per 20 liters of milk (Approximately 0.03%). Most processors could not explain the purpose of salt addition but inferred that excessive salt produces either low yield or low-density curds. Observed cooking time after curd formation varied from processor to processor, however, preliminary tests revealed that holding the curd may influence physicochemical properties. The proposed modifications for this study were to;

1. Increase salt (NaCl) content added to cheese milk
2. Increase cooking time after curd formation

A 3 x 3 full factorial design was used as shown in table 3.1 below

Table 3.1: Experimental variables and their values

Process variable	Treatment 1	Treatment 2	Treatment 3
Salt (NaCl) (%)	0.03	0.1	0.5
Cooking time after rennet addition (min)	20	30	40

Salt content was selected based on pretests. 0.03% was the average amount of salt processors added to cheese milk and therefore served as the control. 0.1 % doubled the amount and 0.5% was the highest level of salt that was preferred by technical selection of consumers who are familiar with the product.

3.2.2 Preparation of cheese

Wagashie preparation on a lab scale was conducted to mimic the traditional process with modifications (Figure 2.4). 500mls of whole unhomogenized creamline milk (MOO-ville Creamery, Nashville, MI USA) was transferred into mini aluminum containers and tempered in a water bath to 30°C. Rennet (Chy-Max Extra, Chris Hansen, Milwaukee, WI, USA) was diluted tenfold and added to milk at a final concentration of 4% (Rayanatou et al, 2017). The use of Chymax Extra as a substitute for *C. procera*, even accounting for different activation temperatures produced the same yield, and insignificant compositional differences (Rayanatou et al, 2017). At thermal equilibrium, rennet with 0.03%, 0.1% or 0.5% salt (sodium chloride) was added to the cheese milk and stirred for 15 seconds. The samples were left undisturbed for 20 minutes to enable curd formation. The samples were immediately transferred into another water bath set to 75°C and the curd was cooked at 20, 30 or 40 minutes. The cooked curds were transferred into plastic 300ml capacity punched cheese molds (PetriStor, Ukraine).

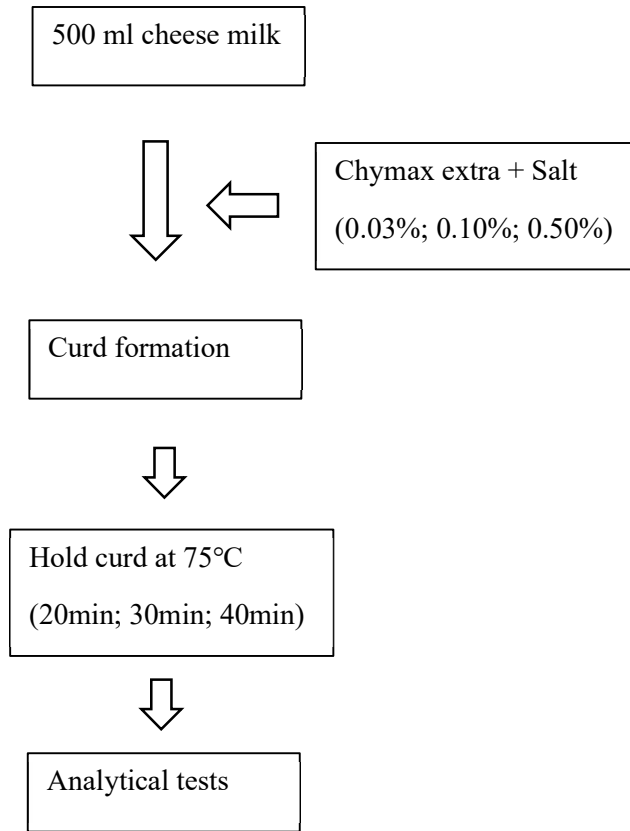


Figure 3.1: *Wagashie* preparation on a lab scale

3.2.3 Spontaneous syneresis and Contraction kinetics

Spontaneous syneresis and contraction kinetics of the cheese was determined during molding by measuring the amount of drained whey as a function of time (Marshall, 1985; Giroux et al, 2014). Whey was collected in graduated measuring cylinders in one-minute intervals for a total of 5 minutes. The total amount of time (t) the cheese was allowed to drain was to mimic the traditional process. Using the integrated rate law for a first order kinetic reaction, the rate constant (k) of syneresis was determined from the formulae below.

$$\int_{[whey]}^{[whey]} = -kdt \quad \text{- equation 1}$$

$$\ln [whey]_t = -kt + \ln [whey]_0 \text{ - equation 2}$$

The curd mass fraction was calculated using equation 3 below, and contraction kinetics after draining/molding was then determined by measuring the curd mass fraction as a function of curd holding time (20, 30 & 40 minutes) (Giroux et al, 2014);

$$\text{Curd mass fraction} = \frac{\text{Curd mass (g)}}{\text{Initial milk mass (g)}} \text{ - equation 3}$$

3.2.4 Flipping behavior

An important specification for *Wagashie* was that the cheese should be able to flip without breaking apart after 3 – 5 minutes of draining to allow small individual curds to knit for completing the molding process, thereby producing a solid cheese unit. For this study, flipping was characterized using the following codes/levels.

- Level 1- Cannot flip, cheese does not maintain its shape upon flipping out of the mold
- Level 2 - Weak flip, cheese spreads when flipped and easily disintegrates
- Level 3 - Solid flip, cheese maintains its shape and stays firm

3.2.5 pH

Cheese pH was measured at three time points; after adding rennet and salt, after curds had formed and after curds had been cooked at either 20, 30 or 40 minutes. A slurry was prepared using 10 g of solid or semi-solid curds and 10 ml of de-ionized water, after which pH measurements were read using a pH meter (AOAC Official Method 920.124).

3.2.6 Yield (Curd mass)

Yield(as-is) and corrected yield was calculated using the formulae below (Rayanitou et al, 2017), considering the dry matter (DM) contents of milk, cheese curds and whey;

$$\frac{\text{Mass of curd (g)}}{\text{Mass of milk (g)}} \times 100\% - \text{yield (as-is)}$$

$$\frac{\text{Milk DM } \left(\frac{\text{g}}{\text{kg}}\right) - \text{Whey liquid DM } \left(\frac{\text{g}}{\text{kg}}\right)}{\text{Curd DM } \left(\frac{\text{g}}{\text{kg}}\right) - \text{Whey liquid DM } \left(\frac{\text{g}}{\text{kg}}\right)} \times 100\% - \text{corrected yield}$$

3.2.7 Proximate composition

Dry matter in the curd and moisture were determined by drying at 102°C according to IDF standard 4A:1982 ISO 5534:1985. Ash was determined using standard AOAC standard methods. The fat content of the curd was determined using the Babcock method and the protein content was determined by the Dumas Method using the LECO protein analyzer.

3.2.8 Statistical Analysis

Experiments were conducted in triplicates and analysis of variance was done according to a 3x 3 factorial design using SPSS version 26. The dependent factors were curd cooking time (min) and salt content (%). The differences were considered significant at p values ≤ 0.05 .

3.3 RESULTS AND DISCUSSION

3.3.1 Spontaneous syneresis and curd contraction kinetics

Syneresis was analyzed using the amount of whey expelled from the curd per minute during molding. Table 3.2 shows the amount of whey extracted from the curd during different cooking times prior to molding and figure 3.2 shows the amount of whey drained during molding over the course of 5 minutes for curd cooking at 20, 30 and 40 minutes respectively.

Table 3.2: Initial amount of whey(ml) spontaneously expelled during curd cooking for 20, 30 and 40 minutes

Salt content (%)	Curd cooking time (min)		
	20	30	40
0.03	136.0 $\pm$ 22.6	265.0 $\pm$ 49.5	280.0 $\pm$ 0.0
0.1	165.0 $\pm$ 7.1	154.0 $\pm$ 5.7	207.5 $\pm$ 24.7
0.5	87.0 $\pm$ 9.9	206.0 $\pm$ 19.8	265.0 $\pm$ 21.2

There were statistically significant differences ($p < 0.05$) in the amount of whey initially expelled during the curd cooking phase. The differences were influenced by both factors as well as their interaction. The most amount of whey was expelled by the control (0.03% salt) at all curd cooking times. Increasing the salt content decreased the initial amount of whey expelled during curd cooking. An overall trend was that the longer the curds were cooked at a constant temperature, the more whey was expelled. According to Guinee (2016), the addition of rennet to milk allows for the hydrolysis of kappa-caseins which results in the gradual aggregation of para-casein micelles that knit to form a solid gel network. As the cooking temperature increases, casein aggregation increases, shrinking the curd and allowing whey to escape. In this experiment, the length of cooking/holding the curd influenced the contraction of the gel network and simultaneously allowed whey to escape as the paracasein network was re-arranged. This is also shown in experiments conducted by Giroux et al 2014.

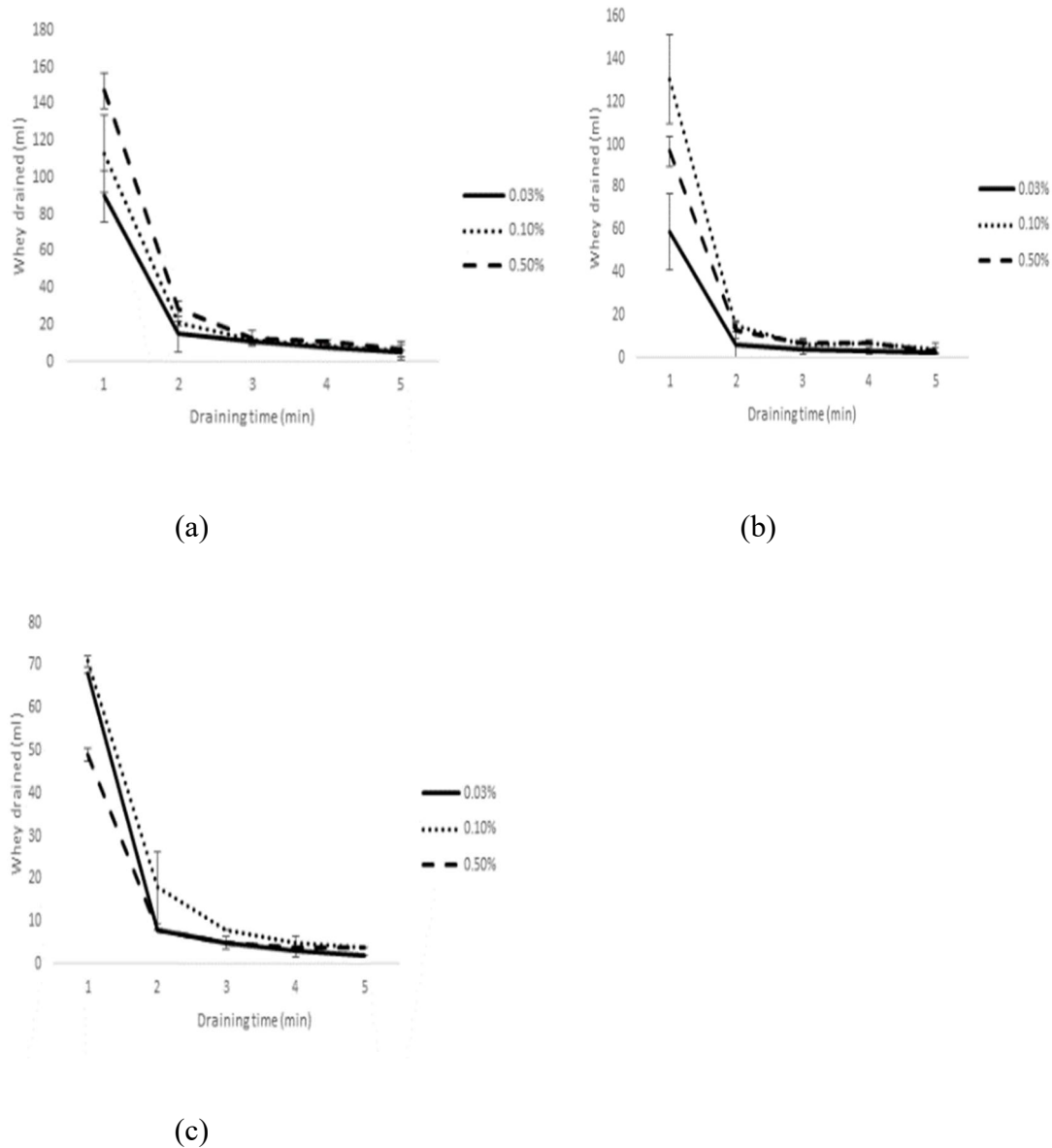


Figure 3.2: Whey drained during molding from curds of different salt contents (0.03%, 0.10% & 0.50%) after a cooking time of (a)20 minutes (b) 30 minutes & (c)40 minutes

Figure 3.2 shows the amount of whey drained over the course of 5 minutes for cheese curds of different salt levels and curd cooking times as the curd contracts further. The least amount of whey drained was from samples cooked for 40 minutes at 75°C. For all curds, the most of amount of whey was lost by 2 minutes. This observation enhances the argument that the exposure to high temperatures on the onset promotes curd knitting and the transformation of the cheese matrix.

Once the gel structure is firm enough, the rate at which whey leaves the curd slows down considerably.

In figure 3.2a, the salt content appeared to significantly affect whey drainage when curds were cooked for 20 minutes. More whey was drained at the 0.5% salt content. However, as the curds were cooked for longer amounts of time, samples with lower salt content exuded more whey during molding (figure 3.2 b, c). This observation shows both salt and temperature can be manipulated to either enhance or decrease whey expulsion in the absence of moisture releasing techniques such as curd cutting or curd stirring. For fresh high moisture cheeses like *Wagashie*, traditional processors may make use of these techniques to attain desired moisture levels of cheese. For the cheese to keep longer, it may be beneficial to increase the salt content and reduce curd cooking time (figure 3.2a). However, if they employ low salt techniques, the recommendation is to cook the curds for a longer period of time (figure 3.2 b, c).

With reference to Guinee and Sutherland (2022) salt influences the extent of paracasein hydration affecting the ability of a casein matrix to lose moisture. The authors state that, depending on the casein content of milk, or the presence or absence of ingredients such as calcium chloride that enhance the formation of firm gels, the early addition of salt, even at low levels can negatively affect gel formation. In this experiment, the addition of less than 1% salt did not appear to influence gel formation as much as heat did on a macroscopic level. In combination with heat however, there was a slight improvement in curd density as evidenced by the least whey expelled with increased amounts of salts.

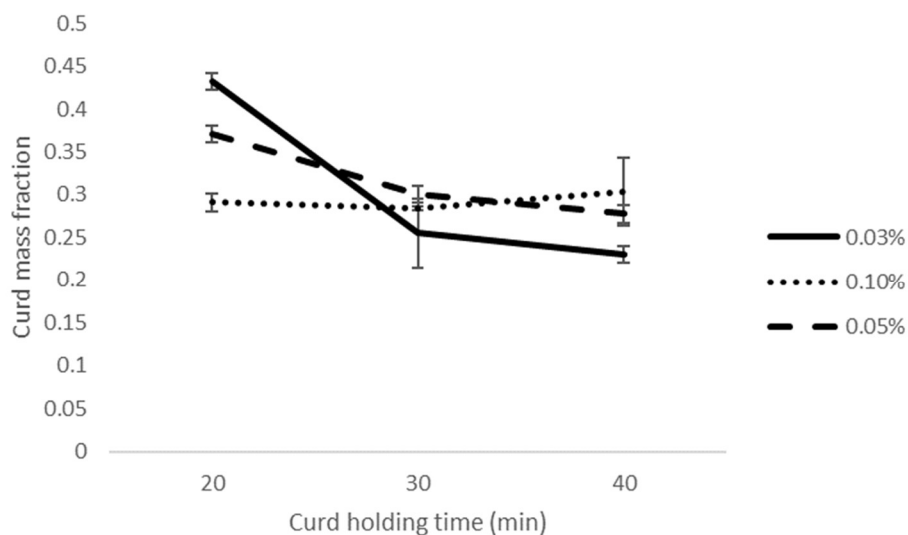


Figure 3.3: Changes in curd mass fraction for cheese curds of different salt contents, held for 20, 30 and 40 minutes at 75°C

Figure 3.3 shows the curd contraction profile of cheese curds of different salt contents held at 75°C for different lengths of time, determined by calculating the curd mass fraction. The weights of the cheese (curd mass) were taken after 5 minutes of allowing whey to spontaneously drain from the curd while simultaneously allowing the final mold to form as the individual curds were knit. Because contraction may have begun immediately curd holding began, whey drained during molding may give a better indicator of how curds contracted during the holding process.

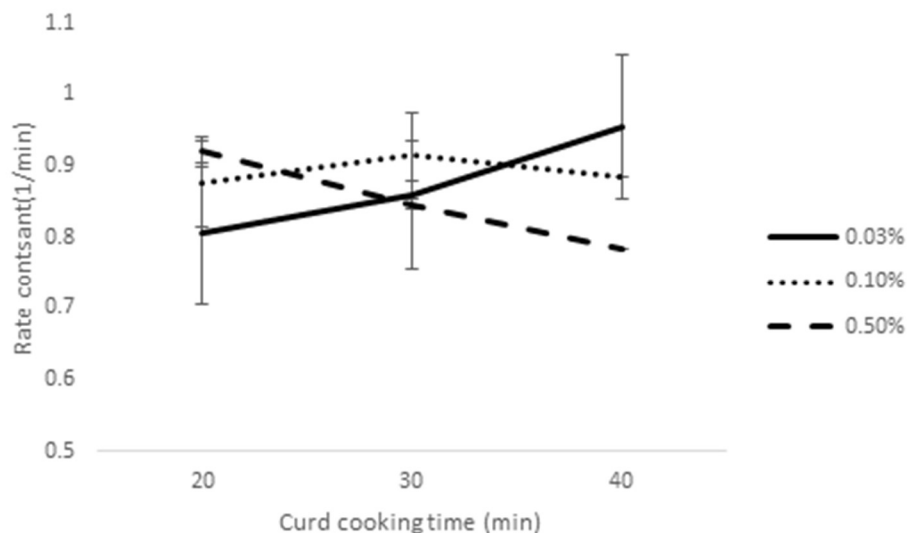


Figure 3.4: Rate constant during syneresis for cheese curds of different salt contents held for different lengths of time

The rate constant was derived using a first order rate of reaction (figure 3.4). The differences in rate constant were not significantly influenced by the salt content or curd cooking time. There were also no statistically significant differences for pairwise and multiple comparisons. At 40 minutes of cooking however, the rate of syneresis was significantly slower for cheese curds with high salt (0.5%). Again, this proves that the amount of whey expelled spontaneously can be manipulated by increasing salt content and decreasing cooking time or decreasing salt content and increasing cooking time.

3.3.2 Cheese yield

When yield was calculated as-is (figure 3.5), curds with the least amount of salt had the highest yield (~43%) at 20 minutes of cooking but tapered off to the least amount (~23%) by 40 minutes of cooking. On the contrary, samples with increased salt (0.1% and 0.5%) started off with lower yields (~31% and ~37% respectively) at 20 minutes and slightly decreased at 40 minutes to ~30%. The yield at 40 minutes for both 0.1% and 0.5% salt however, were significantly higher than the control. According to Hill and Ferrer (2020), increased cheese moisture content can

influence the yield (as-is). The high moisture content of the cheese is synonymous to more whey retention and the perception that the cheese may be heavier. This is evident in table 3.5. The heavier samples at 20 minutes retained ~ 75%. Corrected yield, considering the dry matter content for cheese, milk and whey, showed a different trend. Samples with increased salt (0.1% and 0.5%) were statistically higher than the control at 20 and 30 minutes of cooking the curd. There was a yield increase of approximately 11-15% and 5-9% for these respective times relative to the control. The yield was significantly influenced by the salt content of the cheese. This shows that for the traditional *Wagashie* making process, increasing salt content of the curds by two-fold the current amount is enough to improve the yield of cheese obtained without sacrificing other logistics like fuel.

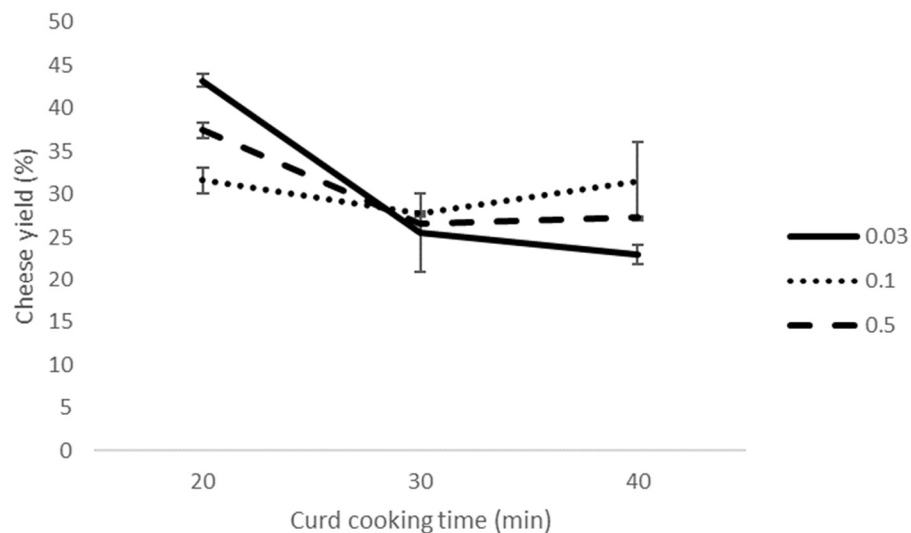
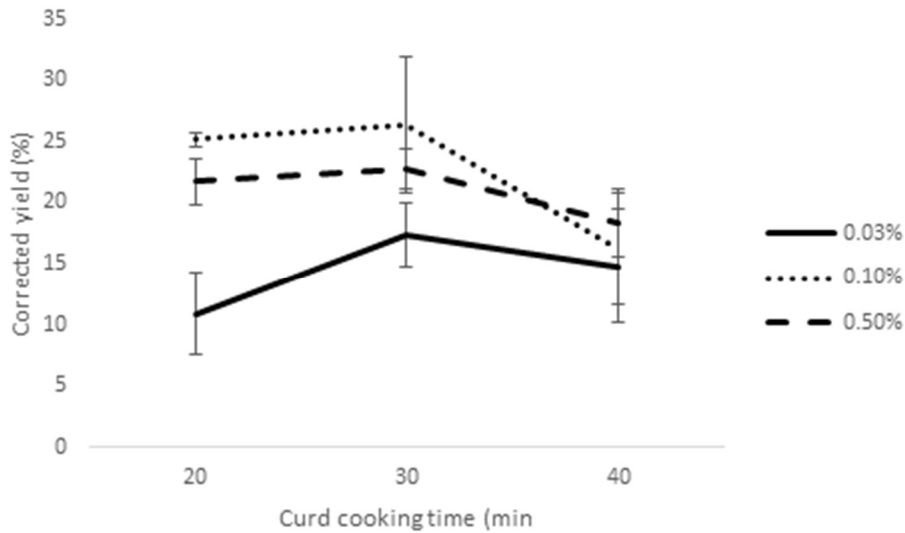


Figure 3.5: Cheese yield for cheese curds of different salt contents held for different lengths of time



(b)

Figure 3.6: Corrected yield for cheese curds of different salt contents held for different lengths of time

3.3.3 Flipping behavior

Flipping behavior did not appear to be influenced by the composition of the cheese curds, but rather the amount of time they were cooked for. The longer they stayed under high temperature conditions (75°C), the firmer the curds were knit and able to flip with ease after 5 minutes. Flipping is an important product specification for *Wagashie* as it determines the final aesthetic mold, obtained weight and subsequent price of each unit of cheese made. It also aids in transportation of the cheese and allows subsequent modifications in retail/foodservice such as cutting into desired shapes, smoking and frying.

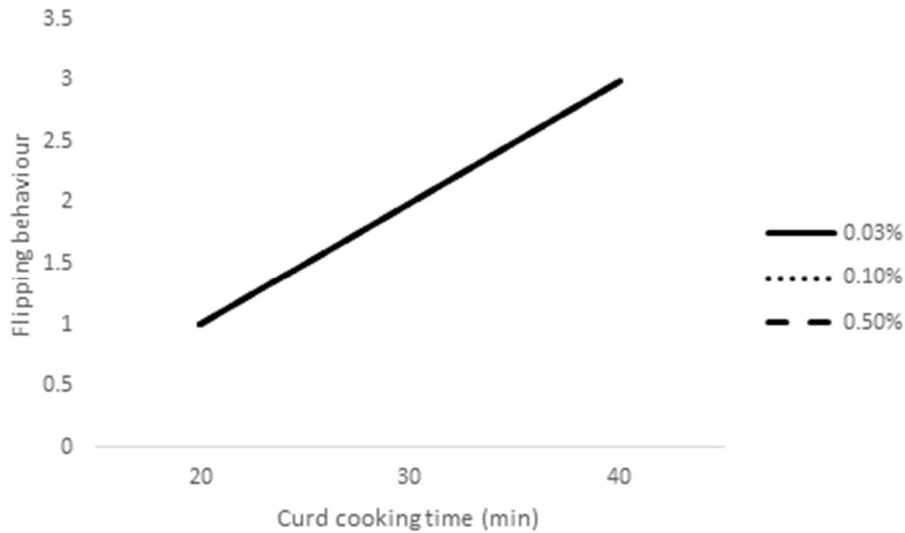


Figure 3.7: Flipping behavior of cheese curds of different salt contents held for different lengths of time

Figure 3.8 shows the different consistencies of cheese at different flipping levels after five minutes of molding. Level one shows cheese that could not flip. The cheese was spreadable, the curds were poorly knit and there was still a lot of whey exuded once the cheese was flipped out of the mold. Level two shows cheese that could flip but would not hold a perfect shape. Like level one, some whey was observed on the surface of the curd, but some knitting had occurred. For level three, a perfectly knit cheese curd was observed with a firm consistency and no whey expelled.



Figure 3.8: Curd consistencies demonstrating flip levels 3, 2 and 1 respectively.

3.3.4 Cheese pH

The acidity of cheese curds measured using pH showed insignificant differences after renneting cheese milk (Table 3.4). The final cheese pH was weak acidic/close to neutral which is similar to other high moisture fresh cheeses like Mozzarella, Ricotta and Cottage cheese. Changes in pH have been shown to influence fat and protein aggregation further enhancing the gel network of cheese, however, this effect is more likely to be observed for ripened/ fermented cheeses (Ong et al, 2020). According to Fox et al (2017), chemical reactions that occur during ripening including proteolysis, lipolysis and glycolysis are influenced by cheese composition and other extraneous variables like temperature, humidity and time. As the macronutrients are modified, significant changes to acidity can be observed and even used as indicators of ripening. This experiment however showed that monitoring cheese pH may not be an important process control indicator. The pH observed was slightly lower than what was observed during field studies (table 2.8), but the disparities could also be accounted for by differences in the composition of milk used and the source.

Table 3.4: pH of cheese curds after renneting, and final product

Salt content (%)	pH after rennet			Final cheese pH		
	20	30	40	20	30	40
0.03	6.415±0.01	6.43±0.02	6.41±0.04	6.37±0.04	6.39±0.01	6.323±0.09
0.10	6.39±0.04	6.38±0.04	6.23±0.03	6.39±0.01	6.33±0.02	6.29±0.11
0.50	6.36±0.01	6.46±0.02	6.49±0.05	6.35±0.03	6.37±0.02	6.41±0.01

3.3.5 Proximate composition

Through this experiment, it was observed that the traditional processing of *Wagashie* may produce cheese curds with approximately 75% moisture, 13% protein, 2% fat and 5% ash. Adetunji and Salawu (2008) reported approximately 61% moisture, 34% protein and 32% fat on a dry matter basis using traditional processing methods. Chikpah et al (2014) also reported approximately 48%

moisture, 14% protein, 28% fat and 4% ash using traditional methods with manual pressing to remove whey. Modifications to processing methods and the use of different coagulating agents make comparisons difficult. The differences in moisture content were significantly influenced ($p < 0.05$) by the salt content, curd cooking time and the interaction between the two factors. The overall observed trend was a decline in moisture levels with increasing cooking time, however the decline was less steep at 0.1% and 0.5% salt. This enhances earlier observations of more whey exuded by high salt cheeses, and cheese curds cooked for longer periods of time. The differences in fat content were significantly influenced by salt content and the interaction between salt and cooking time. From the proximate analysis, holding cheese curds at high heat for a longer time allows for less retention of moisture, and a higher retention of fats. Higher retention of protein however occurs at lower curd cooking temperatures.

Table 3.5: Proximate composition of cheese curds with different salt contents, cooked for different lengths of time

Curd cooking time (min)	Salt content (%)	Moisture (%)	Protein (%)	Fat (%)	Ash (%)
20	0.03	74.75 ± 0.35	13.40 ± 0.10	2.25 ± 0.35	5.40 ± 0.86
	0.10	69.88 ± 0.44	13.09 ± 0.65	1.50 ± 0.00	5.66 ± 0.06
	0.50	74.66 ± 0.49	10.34 ± 0.70	1.75 ± 0.35	6.37 ± 0.69
30	0.03	66.00 ± 2.12	13.16 ± 1.07	2.00 ± 0.00	5.21 ± 1.04
	0.10	68.93 ± 5.69	11.65 ± 2.25	2.00 ± 0.00	6.17 ± 0.33
	0.50	71.01 ± 1.04	10.72 ± 1.72	1.25 ± 0.35	6.74 ± 1.64
40	0.03	58.61 ± 0.16	12.72 ± 0.19	3.00 ± 0.00	4.99 ± 1.19
	0.10	66.69 ± 3.69	10.15 ± 2.19	1.00 ± 0.00	5.84 ± 0.24
	0.50	68.99 ± 0.23	11.20 ± 0.73	2.50 ± 0.71	6.88 ± 0.59

Table 3.6: Statistical results from the univariate analysis of the effects of curd holding time and salt concentration and their interaction on the physicochemical properties of cheese curds

Factor	K (min ⁻¹)		Corrected Yield (%)		pH		Initial whey expelled (ml)		Curd mass fraction	
	F-value	P-value	F-value	P-value	F-value	P-value	F-value	P-value	F-value	P-value
HT (min)	0.020	0.980	4.056	0.055	0.493	0.626	44.661	<0.001	28.710	<0.001
SC (%)	0.457	0.647	9.559	0.006	0.816	0.472	8.700	0.008	1.474	0.279
HT x SC	1.870	0.200	1.871	0.200	1.319	0.334	7.600	0.006	11.540	0.001

Table 3.7: Statistical results from the univariate analysis of the effects of curd holding time and salt concentration and their interaction on the proximate composition of cheese curds

Factor	Moisture (%)		Ash (%)		Protein (%)		Fat (%)	
	F-value	P-value	F-value	P-value	F-value	P-value	F-value	P-value
HT (min)	17.964	0.001	0.107	0.900	0.738	0.505	3.000	0.100
SC (%)	6.792	0.016	4.177	0.052	4.880	0.037	13.286	0.002
HT x SC	4.142	0.036	0.183	0.942	1.069	0.426	7.929	0.005

3.4 CONCLUSIONS

Although in literature the argument for adding salt to cheese milk early in the process may prove detrimental to gel knitting, we established in this experiment that while the length at which curds were held at high temperature did indeed enhance gel knitting traditional processors could stand to benefit from adding less than 1% salt for other benefits like increased yield and decreased syneresis. Adding salt did not influence the ability of cheese curds to flip but holding the curds for longer than 20 minutes at temperatures of 75°C significantly improved molding and aesthetics and the ability for cheese to flip easily out of the cheese molds. This will save traditional cheese processors a lot of time and reduce handling at the end of processing. The experiment also showed that monitoring pH may not be an important process control tool during traditional processing, regardless pH is a good indicator of microbial quality. Finally, increasing the curd holding time and the interaction between holding time and salt content significantly reduced the moisture content of the cheese curds. However, changes in ash, protein and fat were significantly influenced by the salt content only. Regardless of the curd holding time, samples with low salt (0.03%) had the highest ash, protein and fat contents.

**CHAPTER FOUR: THE EFFECTS OF TRAINING WITH SCIENTIFIC ANIMATION
ON KNOWLEDGE, ATTITUDES AND PRACTICES OF TRADITIONAL CHEESE
PROCESSORS IN GHANA**

4.1 INTRODUCTION

Implementing food safety practices among traditional dairy processors often needs education and training of food safety principles but different sized firms often have different compliance expectations, depending on the type of food safety program. For example, in the USA, several authorities (such as the Food and Drugs Authority (FDA), Center for Disease Control (CDC), United States Department of Agriculture (USDA), Department of Health Services (DHS), Environmental Protection Agency (EPA)) handle different sections of the food supply chain to control contamination. The requirement is that training must be conducted and evaluated by trained and certified individuals. In many developing countries, local food authorities also conduct food safety training for different sized firms, however, it is interesting to note that the mode of education/training can be ineffective for traditional processors who are non or low literate depending on the mode of delivery. Omore et al (2009), upon a thorough analysis of dairy products processing in Ghana and Tanzania, concluded that several opportunities existed for intervention particularly with marketing, public health issues, and indigenous processing.

Passing on technical knowledge to unskilled learners with no Food Science knowledge can be ineffective if the wrong educational channels are used. A panel discussion on building food security into resilient and non-resilient cities at the Institute of Food Technologists (IFT 2020 conference proceedings) acknowledged that the translation of high-level science to those who need it the most appears to be problematic because of the failure to break down technical but very important guidelines. For this reason, the development of a culturally appropriate educational animation with content relevant for building key safety features into traditional dairy processing was created and used to train traditional cheese processors in Ghana.

It is hypothesized that the scientific animation will improve the knowledge and attitudes of traditional cheese processors in Ghana towards food safety and hygiene during cheese processing.

4.2 METHODS

4.2.1 Experimental design

Based on feedback from a rapid appraisal, a verified process flow and identified critical control points the following areas were to be addressed in the scientific animation

- Processing area set-up
- Procedures for receiving ingredients
- Ingredient and product specifications and handling
- Improved process controls
- Supplier controls
- Cleaning and sanitation
- Personal hygiene

In addition to expert review of the proposed training material, reference material was also sought from the Code of Hygiene practice for milk and milk products (CAC/RCP 57-2004), the Ghana Code of Hygienic Practices as well as the SSAFE Global Dairy Farming Food Safety Training framework. The creation of the animation followed the steps in the flow diagram in figure 4.1 below. The video was translated into three Ghanaian languages prior to dissemination. These were Fulani, Hausa and Ga-Adangbe.

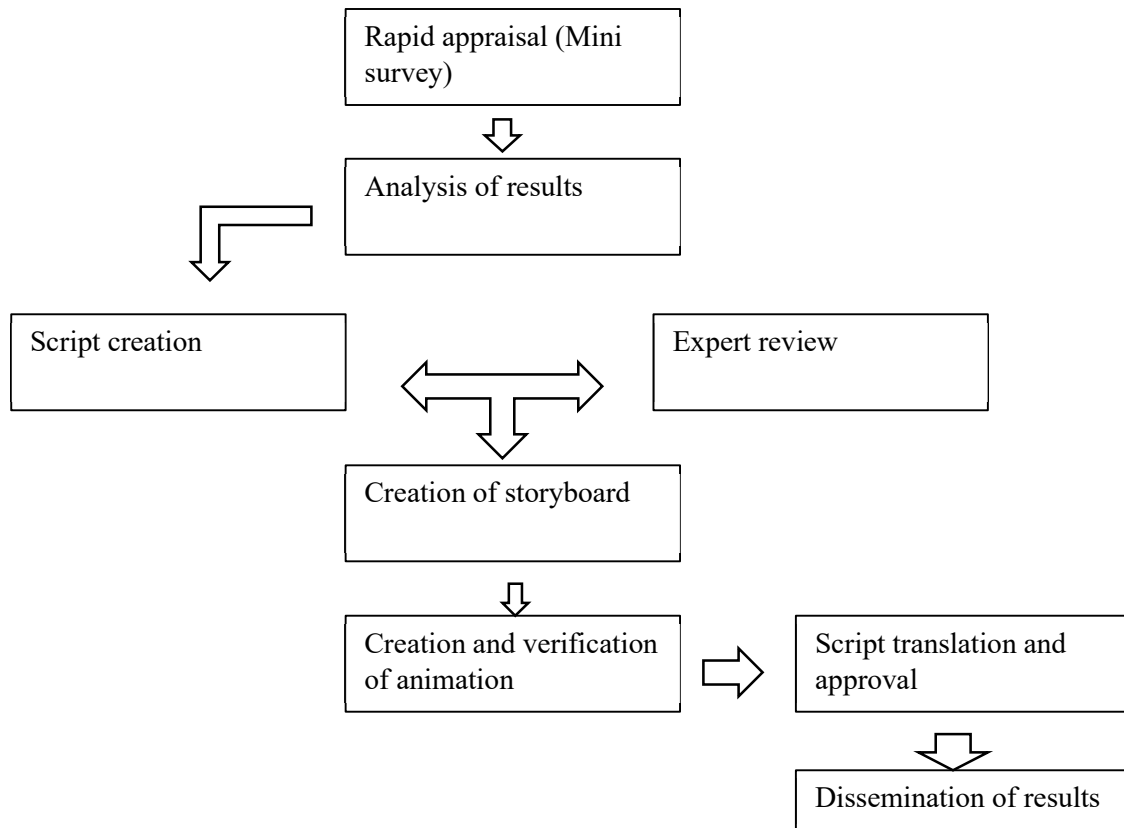


Figure 4.1: Steps for creating the scientific animation

To assess the effectiveness of the scientific animation and adoption of food safety and hygiene practices, a post training knowledge and attitudes survey was conducted as a follow up for the baseline results collected in chapter two. The same questionnaire that was used pretest was used for post-test assessments (Appendix A) and a similar scoring structure as described in section 2.2 was used. Processor training was conducted after the animation was transferred to mobile phones or was viewed on a tablet. The processors were allowed to watch the animations up to three times, ask questions, and discuss the content. Post intervention assessments were performed immediately after training. Processor comments post survey (Appendix A) were documented to help expand answers given in the knowledge and attitudes assessments. An attempt was also made to orally examine processors on new knowledge gained. Overall, post-intervention scores were

compared to baseline scores. The efficacy of the intervention was assessed by measuring changes in knowledge and attitudes.

4.2.2 Statistical analysis

Data were analyzed using SPSS version 26. McNemar's test was used to determine the significance ($P < 0.05$) of differences between the percentage of correct/desired and incorrect/ non-desirable knowledge and attitudes responses observed in pre- and immediate post - intervention sessions. Cochran's Q test was used for repeated measurement. To predict the validity of the outcome of the survey, the "5-to-20 rule" was conducted using the following formula;

$$100 - \left[\frac{\text{respondents at baseline}}{\text{respondents at endline}} \times 100\% \right]$$

- $< 5\%$ - minimal impact on validity of outcomes
- $> 20\%$ - huge impact on validity of outcomes

4.3 RESULTS AND DISCUSSION

4.3.1 Food safety video and messages

The scientific video featured introductory slides that showed the purpose of the video and possible benefits to the processor. Then it went on to explain how the processing area should be set up, and appropriate measures to prevent biological and physical contamination. Finally, the processors were encouraged to be good team players in the dairy value chain. The script used for the animation is detailed below;

Introduction

- This video is meant to introduce you to basic, non-compromising safety and hygiene features that should be incorporated into traditional cheese processing
- This will help you process a safe product for consumer health and help you expand your market reach
- You will also learn about factors that can cause poor yield, product defects or product failure

Setting up the processing area

- It is important that you process in a clean and sanitary environment that is well ventilated
- Do not share your processing area with farm animals, and do not conduct non-processing activities in your processing area; Do not let young children or pets play around in the processing area either
- Make sure your processing area is not close to a dumpsite, open gutter, bushy area, or stagnant water; If you live near the kraal, make sure you have netting installed to keep flies out of the processing area. These steps will help to reduce biological hazards.

- Always clean your area before processing, including getting rid of cobwebs and mending loose thatch roofs. If possible, sprinkle water on the ground to prevent dust from rising as you move in the processing area. These will help reduce physical hazards in the processing area.
- Make sure your process follows a linear flow. This will help prevent cross-contamination
- Do not keep any items including raw material or finished products directly on the floor. Keep all items on a raised platform
- Make sure you wear clean clothes and wash your hands with soap and running water prior to processing. This will help make sure you are not a direct source of contamination to your process.

Processing

- When you receive milk, you must observe the milk to make sure it smells right and has a good creamy color.
- If you receive milk from outside your immediate vicinity, make sure it arrives cold. Warm milk can produce harmful bacteria
- You can check the acidity of your milk to make sure it is safe for processing by using a pH meter
- Before processing make sure you clean the coagulant properly and use clean potable water to strain. Consider using milk to strain to prevent the use of contaminated water.
- Do not dip your fingers into the pot to check how hot the milk is without washing with soap and water. Alternatively, use a clean cup to fetch a small portion, and then dip your finger. You can also use other visual cues such as whey collecting on the surface of the

boiling curd. Preferably, if you have access to a thermometer, it will give you more accurate and consistent temperature readings.

- Consider increasing the amount of salt and the length of time the firm curds are cooked to improve the strength of the cheese curds and overall product quality
- When you finish processing, wash all utensils in three steps; Pre-rinse, wash with soapy water and rinse again with potable water. Use a brush or sponge to scrub wooden baskets. Germs can hide in the wood if it is not done properly. These germs can influence the quality of subsequent batches.
- Allow all utensils to air dry before storage

Important considerations

- Remember that your product is an important dietary source of protein for people of all age groups. Additionally, some age groups such as very young children and elderly people are more susceptible to food-borne illnesses. The value you add to traditional processing is therefore very important
- You will be able to expand your market reach and make more money if you follow these steps to ensure the safety and consistency of your products

The animation is available at no cost at [SAWBO Video Library \(sawbo-animations.org\)](http://sawbo-animations.org)

4.3.2 Validity of survey outcome

Twenty-one (21) processors were available for training and post-intervention survey. According to the “5-to-20 rule”.

$$100 - \left[\left(\text{respondents at } \frac{\text{endline}(21)}{\text{baseline}(26)} \right) \times 100\% \right] = 19.23\%$$

About 80% of the study participants were available for follow up. The impact of the results of the validity of the outcome was therefore high (Dettori, 2011)

4.3.3 Effects of training on knowledge level

Knowledge level is a measure of new knowledge gained from food safety training in comparison to pre-test scores. There was an improvement in knowledge scores for all processors trained compared to pretest results (figure 4.2). Knowledge responses are summarized in table 4.1. With regards to knowledge on hazards and process controls, post-test results showed an improvement in knowledge regarding the role of temperature to the quality of raw milk and finished products. Some processors still disagreed with the statement that the temperature of milk must be measured as an indication of quality. They believed this stipulation was non-practical. Further analyses revealed that these answers were given by rural located processors who lived in very close proximity to a kraal and received milk daily. For such processors, the process of milk cooling would therefore appear irrelevant due to the extremely short transit time of milk from harvesting to processing. Answers were not influenced by previous education status pretest, or whether they had access to electricity. The only influence was proximity to kraal based on location. Knowledge on sanitation indicators was improved overall especially with regards to the role of the environment and personal hygiene in influencing processing outcomes. All processors also agreed that supply chain controls play an important role in processing.

Table 4.2: Knowledge responses from cheese processors post-intervention

	n (%)	
	Reported	
	Yes	No*
Hazards and process controls		
It is important to be familiar with common hazards associated with cheese processing	21 (100.00)	0 (0.00)
The temperature of received milk must be measured as an indication of quality	8 (38.09)	13 (61.90)
Received milk and other raw materials must be inspected for hazards and contaminants before use	21 (100.00)	0 (0.00)
Curd boiling and straining must be controlled to prevent product defects	21 (100.00)	0 (0.00)
Temperature control after cheese processing is critical for quality and safety	21 (100.00)	0 (0.00)
Sanitation		
The sanitation of my processing environment can influence the quality of cheese	21 (100.00)	0 (0.00)
Before and after processing, I must clean my processing area and equipment	21 (100.00)	0(0.00)
During processing I must wear clean clothes and cover my hair	21 (100.00)	0 (0.00)
During processing I must wash my hands if I leave the area or touch another human being or object or use the toilet	21 (100.00)	0 (0.00)
I must avoid processing when I am sick with a communicable disease	21 (100.00)	0 (0.00)
During processing I must immediately remove hazards and adulterants when observed	21 (100.00)	0 (0.00)
Supply chain and other controls		
I should be aware of the types and signs of defects and spoilage that can occur with my products	21 (100.00)	0 (0.00)
It is important to give specifications to raw material suppliers	21 (100.00)	0 (0.00)

*Answers “No” include “Don’t know.”

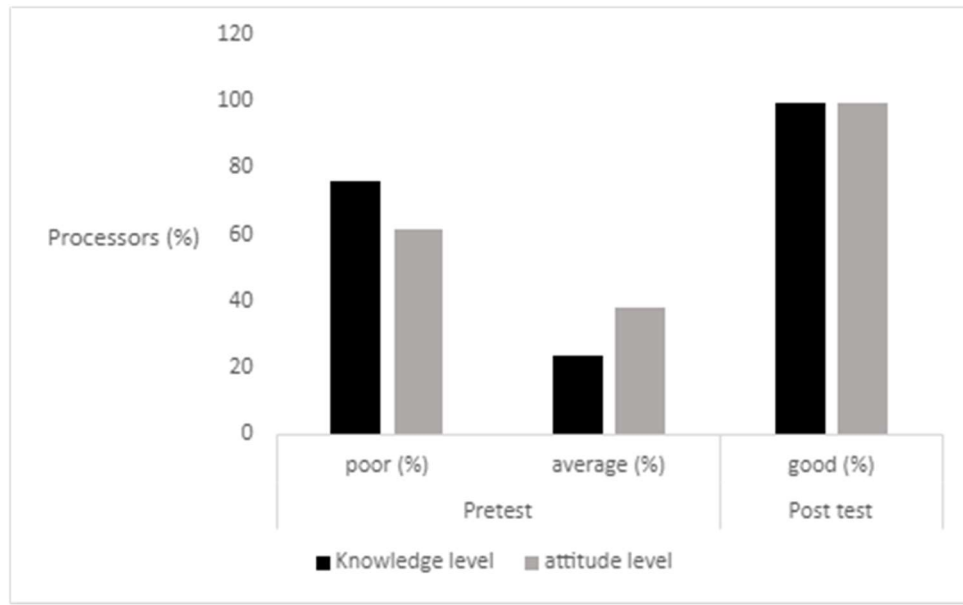


Figure 4.2: Overall effect of intervention on knowledge and attitude of processors

Table 4.3: Knowledge and attitude scores and levels of individual processors before and after intervention

Participant number	total pre-K score	Corresponding level	total post-K score	Corresponding level	total pre-A score	Corresponding level	total post-A score	Corresponding level
3	7	poor	12	good	10	poor	20	good
4	5	poor	12	good	11	poor	20	good
5	10	average	13	good	13	average	20	good
7	10	average	13	good	14	poor	20	good
9	7	poor	12	good	11	poor	20	good
10	7	poor	12	good	12	average	20	good
11	10	average	12	good	13	average	20	good
13	6	poor	12	good	11	poor	20	good
14	6	poor	12	good	11	poor	20	good
15	6	poor	12	good	10	poor	20	good
16	6	poor	12	good	10	poor	20	good
17	6	poor	13	good	11	poor	19	good
18	6	poor	12	good	11	poor	19	good
19	6	poor	12	good	12	average	19	good
20	6	poor	13	good	11	poor	20	good
21	4	poor	13	good	11	poor	20	good
22	8	average	13	good	14	poor	20	good
23	9	average	12	good	12	average	19	good
24	7	poor	12	good	11	poor	19	good
25	7	poor	13	good	13	average	20	good
26	6	poor	13	good	11	poor	20	good

*Pre – pre intervention; Post – post intervention; K- knowledge; A - attitudes

4.3.4 Effects of training on attitude level

Attitudes measured the extent to which processors believed or disbelieved a food safety statement. Rather than measuring attitudes based off previous experiences and knowledge, attitudes were measured to determine if messages given in the training video could change previously held perceptions of the processors. In pretest scores, no processor had good attitudes towards food safety statements, but after training all processors scored high meaning their perceptions towards food safety in cheese processing changed (table 4.3). Contributors to prior poor or average attitudes included disagreeing or being neutral to statements related to various

aspects of processing prior to training. For example, no processor previously agreed that milk suppliers and cheese retailers played key roles in the safety of cheese products. This suggests that processors do not perceive themselves as key players in the dairy supply chain. All processors were also neutral to the suggestions that they could sell their products beyond formal markets pre-training. After training, this perception changed. A few factors that could have persuaded the change included the fact that food safety requirements had been simplified through the animation and did not require additional technology for traditional set up.

There were no statistical differences among demographic factors that contributed to changes in attitudes (Appendix B). Dependent factors that may have influenced knowledge and attitude level pretest such as age, location type, education status and electricity were correlated with knowledge level and attitude level pretest. Education influenced knowledge level and electricity influenced attitudes. None of these dependent variables influenced the knowledge level or attitude level after the intervention.

Table 4.4: Attitudes towards food safety and hygiene post intervention

Statements	Agree	n (%)	
		Disagree	Neutral
I believe that knowing about hazards is important	21 (100.00)	0 (0.00)	0 (0.00)
I believe that process controls can be implemented for traditional dairy products	21 (100.00)	0 (0.00)	0 (0.00)
I believe that suppliers and retailers must follow specifications to maintain product quality	21 (100.00)	0 (0.00)	0 (0.00)
I believe that training is important for traditional processors	21 (100.00)	0 (0.00)	0 (0.00)
I believe that processors must be concerned about product defects	21 (100.00)	0 (0.00)	0 (0.00)
I believe that if one product is defective or adulterated, the entire batch must be thrown out or reworked	21 (100.00)	0 (0.00)	0 (0.00)
I believe that maintaining a cold chain is important to extend shelf life	21 (100.00)	0 (0.00)	0 (0.00)
I believe that hygienic practices and environmental hygiene influence product quality	21 (100.00)	0 (0.00)	0 (0.00)
I believe that food safety plans will help with meeting standards	21 (100.00)	0 (0.00)	0 (0.00)
I believe that a food safety plan will help sell beyond informal markets	21 (100.00)	0 (0.00)	0 (0.00)

4.3.5 Processor comments

4.3.5.1 Challenges faced with using the scientific animation

4.3.5.1.1 Animation content

About 47% of processors mentioned that milk cooling at the collection point was either impractical, not feasible or not necessary. Some processors mentioned that dairy farms do not have milk cooling facilities since they sell very small quantities to individuals. In cases where people were not in close vicinity to a kraal, they would pick up milk that had been harvested prior to their arrival or based on the dairy farmer's demand for the day. For those near the kraal, harvested milk spent a relatively short time waiting to be processed and so, cooling or the investment in cooling equipment was not important. These issues highlight the potential usefulness of milk cooperatives or milk hubs that can serve as a central collection point for processors. This will allow the required testing requirements to be fulfilled, may aid in standardizing the nutritional content and the price

of commingled milk, and improve the livelihoods of traditional processors (Kumar et al, 2019; Rao et al, 2019). Such facilities are currently not employed in the dairy supply chain in Ghana.

Other processors mentioned specific issues such as standardizing the amount of salt to add to cheese milk. These processors were part of the few who did not include salt in processing at all prior to training. The use of salt for *Wagashie* processing is employed in other parts of West Africa routinely for benefits such as preservation and flavor (O'Connor, 1993; Omore et al, 2009). In the preceding chapter, the effects of salt have been shown to improve yield, moisture content and flipping behavior.

Finally, a few processors acknowledged that they would need an entirely new structure to process cheese as they currently shared the area with farm animals. This was going to require processing space, the availability of materials for construction and the willingness to invest based on the financial output of the processing operation.

4.3.5.1.2 Animation technology

Consistent with early SAWBO experiences (Bello-Bravo, Lutomia, et al., 2020), difficulties around technological access to the training meant that many processors were not able to receive the content on personal phones. Issues ranged from no phone to no streaming capability, and poor maintenance of smart phones. Also consistent with SAWBO's experience (Rodríguez-Domenech et al., 2019), none of the cheese processors were formally educated and could not independently assess the information from the SAWBO website or YouTube. This underscores the critical emphasis in Ribot and Peluso (2003), that user's ability to *access* material must include its availability *and* their ability to use it. Recognizing this, SAWBO affords organizations and change agents with the ability to access SAWBO materials to then effectively deliver it to those who cannot access it (because of technological, educational, or linguistic issues, or even simply

geographic isolation). Hence, in the present case, the way to get the animation to individuals was to share or transfer videos to trusted neighbors and educated household members who were present at the time of training.

4.3.5.2 Processors' understanding of the content of the animation

There were no issues relating to understanding the content of the animation. This was particularly because the native language of the processors was used. This allowed technical scientific jargon to be broken down for simplification of the content (Abdulaziz, 2014; Kueffer & Larson, 2014; Babaci-White, 2017). A previous barrier identified pretest was that most processors were not aware of standards and specifications pertaining to cheese processing due to the language barriers, educational barriers, and location barriers. Smallholder processors who did not have access to electricity, smart phones and did not live in urban areas may not be privy to some information propagated through certain media such as print, radio, television or internet regarding food safety standards and specifications. Most did not know about Ghana's Food and Drugs Authority. Very few had interacted with health inspectors through the process of health certification, and these were due to other food service activities, not cheese processing.

4.3.5.3 Processors' ability to recall new information from the scientific animation

Because measuring practices after training was not included in the scope of the study, an attempt was made to recollect new knowledge that processors may have gained. Processors were asked to recollect material from the interviewer. Most processors recollected information that they said was new to them, or that they had not given attention to prior to training. These included the importance of hygiene within and external to the processing area, making modifications to the processing area to minimize biological/microbial and physical hazards, personal hygiene, using a

three-step cleaning process for utensils, modifying salt content, avoiding the use of non-potable water and how to improve yield and quality for a wider consumer base and higher incomes.

4.3.5.4 Processors' thoughts on product safety prior to training and selling beyond informal markets

To answer if they felt their products were safe prior to processing, about 20% of the processors said, “unintentionally yes”, about 33% said “definitely yes” and the rest said, “probably yes”. Processors buttressed their answers by explaining where they possibly went wrong. Some said they worked near a kraal or other livestock and were not aware cross-contamination could occur and a few others said they did not know microbial contamination could be introduced in several ways through processing.

About 90% of the processors were optimistic that they could sell their products in formal marketing outlets like supermarkets, gas stations, etc. if they followed the instructions of the animation. They were optimistic about the potential for growing their consumer base and making more money. Some highlighted that they currently do not produce enough to sell to a larger consumer base than they could currently handle, and the seasonality and subsequent availability of milk was a major factor. Again, introducing milk collection points in the dairy supply chain could help alleviate this problem by making commingled milk more readily available to processors of dairy milk.

Table 4.5: Variance and co-variance of pre-and post-knowledge and attitude scores

Group	Variance	Covariance
Pre-knowledge scores	2.69	
Post-knowledge scores	0.25	
Pre-attitude scores	1.45	
Post attitude scores	0.19	
Pre-knowledge x Pre-knowledge		2.56
Pre-knowledge x Post-knowledge		0.08
Post-knowledge x Post-knowledge		0.24
Pre-attitude x Pre-attitude		1.39
Pre-attitude x Post attitude		0.04
Post attitude x Post attitude		0.18

Table 4.6: Analysis of variance for pre and post knowledge and attitude scores

Source of variation	F-value	P-value	F-critic
Knowledge pre and post scores	214.34	1.16 E-17	4.08
Attitudes pre and post scores	855.03	1.29 E-28	4.08

4.4 CONCLUSIONS

In conclusion, it was feasible to create a scientific animation to train traditional cheese processors on the importance of food safety and hygiene during processing. The animation was also able to draw attention to internal and external factors in the processing environment that can contribute to low quality products. The ability to translate and disseminate the animation into the processors' local languages broke down educational barriers that previously prevented knowledge access.

The results showed that overall knowledge and attitudes of smallholder processors can be positively influenced by intrinsic and extrinsic variables influencing the processor as well as communication through extension as proposed by Meijer et al (2015). Even though attitudes can be deep-seated and include personal biases, the information in the intervention used examples pertaining to processing conditions that were directly observed to explain why processors might want to consider certain previous beliefs as inaccurate. Although the role of the temperature of the milk prior to processing was not widely accepted because of individual circumstances pertaining to milk collection, processors picked up new knowledge, recognized hazards more easily and were more confident about introducing their products to formal marketing systems.

Finally, the hypothesis was proven true. The scientific animation improved the knowledge and attitudes of traditional cheese processors in Ghana towards food safety and hygiene during cheese processing.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Firstly, the study was able to document firsthand experiences and practices of traditional cheese processors as important actors of the informal dairy industry. It was discovered that there were insignificant differences in processor knowledge, beliefs, and practices despite varying socio-demographic variables. All cheese processors practiced what had been learned from household predecessors, owned their operations and were wholesale distributors of cheese. Risk behavior and processing variables that helped define and refine critical control points and enhance overall product quality were identified. Practices traditional cheese processors engaged in that influenced quality were identified and categorized into processing-related (raw milk storage, coagulant processing, heat regulation during processing and the inclusion/exclusion of salt as an ingredient) and non-processing related (milk seasonality, animal husbandry practices, distance from farm to processing site) factors.

Secondly, the role of salt and curd cooking length were further explored on a lab scale to test processor theories and the effects on the physicochemical properties of *Wagashie* cheese curds. It was shown that the addition of salt improved cheese yield and decreased syneresis while both salt and increased curd cooking times were beneficial for gel structure, cheese molding and reduced cheese moisture content. These findings may directly be implemented in the field to help save fuel during processing, improve handling post-processing, and create desired outcomes.

Thirdly, a training and extension module was developed to contribute to the lack of resources that are appropriate for introducing food safety principles in cheese processing to non-literate smallholder processors. Created in the form of a scientific animation and translated into local languages, the material covered basic principles of sanitation, processing area set-up, procedures for receiving ingredients, ingredient and product specifications and handling, improved

process controls (the inclusion of salt and increasing curd cooking time) and supplier controls. The training material showed remarkable success in improving the poor knowledge and incorrect attitudes of traditional cheese processors. Because of the technology used, processors now have constant access to the training material, at their own convenience, as a resource for improving their processing outcomes.

5.2 LIMITATIONS OF THE STUDY

For the first aim, a small sample size was used for the survey mainly because the work was conducted during surges of COVID-19 in Ghana. Movement was restricted, and economic hardships reduced the number of active processing centers. In places where processing was ongoing, efforts were made to include a representative number of processors. Another limitation was that many standard questionnaires regarding food safety and hygiene were not applicable to this group of processors. The questionnaire therefore had to be modified several times after pre-testing to capture salient concerns.

During training for the third aim, many processors reported issues with receiving the animation on devices that they had easy access to. In cases where their phones could not receive the animation, another family member or a trusted neighbor received the animation on their behalf. This may create issues with easy access to the information as and when it is needed.

5.3 RECOMMENDATIONS

A follow-up study on traditional processors to assess the adoption of suggested practices from the training video was not conducted as part of this study. To ensure processors benefit fully from the experience, it is important to test the retention of learned information, and the ease of incorporation of suggested improvements especially since a few processors had raised concerns with the need to invest in processing infrastructure to reduce hazards in the processing environment.

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APPENDIX A: QUESTIONNAIRE

Knowledge Attitudes and Practices survey questionnaire for traditional dairy processors in

Ghana (pre- and post-intervention)

Section 1: Processor characteristics and demographics (pre-intervention)

1. Name and code
2. Age (years)
3. Local languages spoken
4. Type of Location (rural/urban/peri-urban)
5. Educational background [None, primary school, secondary school, tertiary]
6. Is dairy processing your primary occupation (yes/no)
7. Have you attended any training for dairy processing? If yes, was this formal or informal
8. Type of operation [self-owned, shared ownership, apprentice, employee]
9. What retail outlet or mode do you use (hawking, gas station, informal market, food service, supermarket, distributor/wholesaler, other)
10. Do you have a health certificate from the local Municipal Assembly?
11. Do you have access to the free use of a smartphone?
12. Do you have access to electricity?

Section 2: Knowledge of food safety and hygiene for dairy processing/processor supply chain (pre- and post-intervention)

Score: Yes (1pt), I do not know (0pt), no (0pt)

Hazard analysis

1. It is important to identify and evaluate hazards during traditional dairy processing

Process controls

2. The temperature of milk received must be measured at reception
3. Received milk and other raw materials must be physically inspected for hazards
4. Curd boiling and straining must be controlled to prevent product defects
5. Temperature control after cheese processing is critical for quality and safety
6. The temperature of the products must be checked after processing

Sanitation control

7. The sanitation of my processing environment can influence the quality of cheese
8. The processing area must be cleaned and sanitized before, during, and after processing
9. During processing I must wear clean clothes and cover my hair
10. During processing, I must wash my hands if I leave the processing area or touch another human being or object or use the toilet
11. I should not do any processing or retailing when I am sick with a communicable disease
12. During processing I must immediately remove hazards and adulterants when observed

Supply chain controls, and other controls

13. I must know the types or signs of defects and spoilage that can occur with my products
14. Raw material suppliers must be given specifications for ingredients

Section 3: Attitudes or beliefs about hygiene and safety during traditional dairy processing (pre- and post-survey)

Score: Agree (2 pts), Neutral (1 pt), Disagree (0pts)

1. As a processor, I should be concerned about the type of hazards I can identify during processing
2. I believe that implementing process controls can be implemented for traditional dairy processors
3. I believe that it is my duty as a processor to ensure my suppliers and retailers follow specifications to ensure the quality of my product is maintained
4. I believe that milk processing, safety, and hygiene training is especially important for traditional processors
5. I believe that traditional dairy processors should concern themselves with the types of product defects of the products they manufacture
6. I believe that if a single product is defective/adulterated or spoiled the entire batch must be discarded or re-worked
7. I believe that maintaining a cold chain after processing is important to extend product shelf life
8. I believe that my hygienic practices and the sanitation of my environment influence the quality of my products
9. I believe a standard food safety plan will help me meet legal standards for my products
10. I believe that if I have a food safety plan I can sell beyond informal markets

Section 4: Practices during Traditional Dairy Processing (pre and post-survey)

1. How is milk handled prior to processing
2. How long is milk kept prior to processing
3. How do you monitor time and temperature during processing
4. What treatment is given to the cheese curd
5. What instructions are given for handling and consumption

Processor comments: (pre-survey only)

- What do you think is your biggest challenge to having a standard food safety plan?
- Do you think traditional dairy products are better than modern ones? Why or why not?
- Do you think your products are unsafe and unsanitary?
- Do you think consumers believe traditional products are unsafe and unsanitary?
- Do you think traditional dairy products can be sold at formal marketing outlets like supermarkets, gas stations, etc.?

Processor comments: (Post survey only)

- What challenges did you face with using the scientific animation? (content and technology)
- Did you understand the content of the animation?
- Did you learn anything new from the scientific animation?
- Do you think your products were unsafe and unsanitary prior to training?
- Do you think consumers believe traditional products are unsafe and unsanitary?

- Do you think traditional dairy products can be sold at formal marketing outlets like supermarkets, gas stations, etc.?

APPENDIX B: SUPPLEMENTARY MATERIAL

Table B.1: Population distribution of demographic variables and knowledge levels pre and post intervention

Demographic variables	Pretest (n=26)			Post-test (n=21)		
	Poor (%)	Average (%)	Good (%)	Poor (%)	Average (%)	Good (%)
Age						
18-30y	43.8	60.0				47.6
31-50y	25.0	40.0				28.6
51y +	31.3	0.0				23.8
Location type						
Rural	68.8	60.0				66.7
Peri-urban	18.8	40.0				23.8
Low income urban	12.5	0.0				9.5
Education status						
None	87.5	20.0				71.4
Primary school	12.5	40.0				19.0
Secondary school	0.0	40.0				9.5
Access to electricity						
Yes	68.8	60.0				66.7
No	31.3	40.0				33.3

Table B.2: Population distribution of demographic variables and attitude levels pre and post intervention

Demographic variables		Pretest (n=25)			Post-test (n=21)	
Age	Poor (%)	Average (%)	Good (%)	Poor (%)	Average (%)	Good (%)
18-30y	53.8	37.5				47.6
31-50y	7.7	62.5				28.6
51y +	38.5	0.0				23.8
Location type						
Rural	69.2	62.5				66.7
Peri-urban	23.1	25.0				23.8
Low income urban	7.7	12.5				9.5
Education status						
None	92.3	37.5				71.4
Primary school	7.7	37.5				19.0
Secondary school	0.0	25.0				9.5
Access to electricity						
Yes	76.9	50.0				66.7
No	23.1	50.0				33.3

Table B.3: Crosstabulations for pre and post knowledge and attitude levels

		Post knowledge level		
		Average	Good	Total
Pre knowledge level	Poor	2	14	16
	Average	0	5	5
Total		2	19	21
		Post attitude level		
		Good	Total	
Pre attitude level	Poor	13	13	
	Average	8	8	
Total		21	21	