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## Abstract

Large amount of consumption of sodium in foods leads to several health problems like high blood pressure, heart stroke, and hypertension. Reducing sodium content in process cheese is expected to reduce sodium consumption by United States (US) consumers. The objective of this study was to analyze and evaluate the effect of potassium chloride (KCl) and potassium based emulsifying salts as a salt (sodium chloride, NaCl) replacer on sensory and textural properties of pasteurized process cheese. Control (100% NaCl), Treatment 1 (100% KCl) and Treatment 2 (50% NaCl + 50% KCl) samples were produced and analyzed for textural properties including hardness, cohesiveness, springiness, chewiness and gumminess and sensory properties including color, hardness, bitterness, saltiness and chewiness. The replacement of NaCl using KCl had significant effect on sensory properties including hardness, bitterness and saltiness of process cheese. It has also significant effect on texture property including hardness. Therefore, combination of NaCl and KCl was recommended to use as salt replacer in the process cheese with other ingredients, which can mask the bitter flavor produced by KCl.

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**Table of Contents**

## List of Tables

## List of Figures

# Chapter I: Introduction

Salt (sodium chloride, NaCl) is the oldest food seasoning, which provides one of the important basic human tastes (saltiness) and preserves foods to extend the shelf-life. Salt is one of the required components by body for normal physiological activity. Salt mainly consists of two elements: sodium and chloride. There are various types of salts available in the market depending on the size and refining process. Although salt has various unique functions for the human body as well as in food processing, high amounts of sodium consumption is a raising social problem in the United States (US) because it is increasing the risk of heart attack and high blood pressure (Doyle, 2008). In 2005-2006, the estimated 29% of US adults had hypertension and around 28% of adults had prehypertension, which is increasing the risk of heart disease and stroke (Ostchega, et al., 2008). These two diseases are the first and third leading diseases responsible for the death in the United States (Murphy et al., 2012). Cardiovascular disease (CVD) is the result from high intake of salt by food (De Wardener, et al, 2004). The United States Department of Health and Human Services (HHS) and the United States Department of Agriculture (USDA) recommends no more than 2,300mg/day of sodium consumption for a healthy adult, but the average sodium consumption in the US is around 3,436 mg per day which is much higher than the recommendation (USDA, 2010). World Action on Salt and Health is one leading group at the international level, which is working with 80 countries industries and government to reduce sodium intake in the human body (Wash, 2005).

Process cheese is a dairy product, which has the highest sodium content product among dairy products. The United States is one of the leading states in the production of process cheese and produces around 30% volume of total world productions (Award et al., 2004). According to the National Agricultural Statistics Service in 2010, total cheese production was 10.4 billion pounds (USDA, 2011). Cheddar cheese has around 620 mg sodium/100 g cheese, low moisture skim mozzarella cheese has 512 mg sodium/ 100 g and process cheese has 1,488 mg sodium/100 g (Agarwal et al., 2011). According to the Code of Federal Regulations (CFR), pasteurized process cheese food (PCF) has to meet the legal requirements of minimum 46% fat and maximum 44% moisture (CFR, 2006). Pasteurized process cheese spread (PCS) has separate standards to meet the legal requirement of a minimum of 40% fat and a maximum of 60% but not lower than 44% moisture (CFR, 2006). The consumption of processed cheese has been increasing more and more and its suitability to use depends on the textural and flavor characteristics of the raw/unheated cheese. Shredded cheese is used on bread, crackers, table spread, sauces and dips. Process cheese is used as ingredients for various foods such as burgers, toasted sandwiches, pasta sauces and poultry products.

Generally, process cheese is made from normal cheese with various ingredients such as emulsifying salt, extra salt, and food colorings for the homogeneous mass condition during heat processing. Unprocessed cheese usually can be separated into a molten protein gel and liquid fat by heat treatment. Therefore, emulsifying salt such as sodium phosphate, potassium phosphate, tartrate and citrate has an important role to protect the separation of protein and fat. Emulsifying salt reduces the tendency for tiny fat globules to attach on the surface of protein in the molten cheese. Apart from the ingredients manufacturing process, it also affects the process cheese quality (Garimella et al., 2006). Process cheese is widely used with several applications so final characteristics of product quality is very important. To get the good quality of process cheese several parameters have to be considered including selection of ingredients, processing method, cooking temperature, speed of mixing, and rate of cooling (Garimella et al., 2006).

All properties of process cheese are controlled by the type and amount of natural cheese, salts, emulsifying salts, and other ingredients, which are added during the manufacturing process. Natural cheese is one of the main ingredients in making process cheese. Some of the functional properties of process cheese including texture and meltability were greatly affected by type and amount of natural cheese (Kappor & Metzger, 2008). Researchers have highlighted that physicochemical characteristic such as calcium content, phosphorous content, residue lactose and pH of a natural cheese influence the functional and rheological properties of the process cheese (Biswas et al., 2008). Emulsifying salt (ES) is an important ingredient of process cheese to get smooth emulsified texture process cheese (Lu et al., 2007). Widely used emulsifying salts in process cheese are phosphates and citrates, which are the mixture of monovalent cation such like sodium and a polyvalent anion such like phosphate and citrate.

Emulsifying salts also promote various types of physicochemical condition of final process cheese products. Commonly, sodium salts of citrate and phosphate are used as emulsifying salts in process cheese manufacturing (Dimitreli et al., 2005). Emulsifying salts are important factors which can control the functional properties of process cheese. The types and amount of emulsifying salts have a large effect on the quality of process cheese. Emulsifying salts provide the emulsifying property to cheese proteins. Emulsifying salts removed calcium from protein system and solubilized the protein and also stabilizes the fat and control final pH of process cheese (Mayer, 2001). Emulsifying salts individually contribute around 50% of sodium in process cheese. There are three main sources which contribute the sodium to the process cheese, include type of natural cheese used, sodium chloride and emulsifying salts (Karahadian & Lindsay, 1984). For producing low sodium process cheese the amount of sodium chloride (NaCl) and sodium based emulsifying salts has to reduce. Besides that sodium chloride is the main ingredient, which is responsible for the clean salty taste of process cheese. Reduction in sodium chloride and sodium based emulsifying salts quantity largely affect the functional and sensory properties of process cheese. Considering this all challenges reducing sodium content in process cheese is not an easy task.

Cheese texture is a very important part to study structural properties of process cheese and the texture profile analysis is used to measure the textural properties of solid foods. Shirashoji et al., (2006) indicated that reducing sodium content in process cheese with lowering emulsifying salts quantity increases the processing time and affects the cheese texture. The instrumental methods for texture analysis are also a good alternative way instead of sensory analysis and it has benefits such as cheaper, quick and simple. The most common application is the use of the 2 –bite compression for determination of hardness, elasticity, adhesiveness, cohesiveness, chewiness and gumminess (Everard et al., 2007).

Process cheese has several benefits compared to natural cheese such as extended shelf-life, resistance to separation for cooking, and homogenous product's condition because of heat processing and emulsifying salts. However, process cheeses provide a high amount of sodium intake for daily diet and it is needed to reduce sodium amounts from their formula. Usually the primary supplier of sodium in food is mainly salt (sodium chloride, NaCl) and unionized salt contain by weight 40% of sodium. Potassium chloride (KCl) and potassium based emulsifying salt (potassium phosphate) have been studied as a salt (sodium chloride, NaCl) replacer in mozzarella cheese (Ayyash & Shah, 2011a). Studies results indicated that the usage of potassium chloride in foods as salt replacer shows beneficial effects in person who has a hypertension problem caused by high sodium consumption (Karagozlu et al., 2008).

The objectives of the study were to determine the effects of potassium chloride (KCl) and potassium based emulsifying salt as a salt (NaCl) replacer for minimize or avoid bad effects of high sodium on our health. To analyze the effect of fully or partially substitution of NaCl with KCl (only NaCl, only KCl , 50% NaCl and 50% KCl) on sensory property including color, saltiness, bitterness, chewiness hardness and on textural properties such as hardness, cohesiveness, chewiness, springiness, gumminess using texture profile analysis.

# Chapter II: Literature Review

## Introduction

Process cheese (PC) is an important part of the diet of the American people. Because of the widely use of process cheese it comes under one of the main cheese varieties (Sorensen, 2001). Process cheese is a dairy food prepared by blending of natural cheese, sodium chloride, emulsifying salts, and other dairy and non-dairy ingredients with providing heat and continuous mechanical agitation to produce the homogenous product (Thomas, 1973). The natural cheese has calcium and phosphate join network, which is disturbed by the added emulsifying salts. This disturbance leads to breakage of protein linkage available in natural cheese and exposes the hydrophilic and hydrophobic part of main casein protein. In addition to this when mechanical force and heat is given, the hydrophilic and hydrophobic sections interact with the fat phase and liquid phase. As a result, we are getting uniform closely knit protein network (Caric et al., 1985; Berger et al., 1998; Ennis et al., 1998). The physical and chemical property of process cheese mainly depends on the microstructure of process cheese (Kapoor & Metzger, 2008).

This chapter will discuss the background of process cheese, FDA/ Code of Federal Regulation Specification for process cheese, reducing sodium in processed cheese, factors affecting functionality process cheese, microbiology of process cheese, and chemical property of process cheese sensory and textural properties.

## Background of Process Cheese

The history of process cheese began around the early 20$^{th}$ century with the idea to increase shelf life of natural cheese and other way to sell natural cheese. Process cheese was invented by Fritz Stettler and Walter Gerber of Gerber Company (Switzerland) in 1911. Swiss cheese took as a natural cheese source and with heat melts it first and then adds sodium citrate for an achieved emulsified and homogenous final product. Five years later in 1916, process cheese came to the United States by J. L. Kraft for the purpose to improve the natural cheese shelf life (Kapoor et al., 2007). In 1930, process cheese manufacturing became very popular because during that time market emulsifying salts were available (Berger et al., 1998). Process cheese became an important product worldwide because of its excellent shelf life over wide range of temperatures, especially in the developing country (Mann, 2004).

**FDA/ Code of Federal Regulation- Definition**

Process cheese is legally categorized by the Code of Federal Regulations (CFR) (21 CFR 133.169 to 133.180) into three major categories and depends on fat and moisture content. The categories are: Pasteurized Process Cheese (PC), Pasteurized Process Cheese Food (PCF) and Pasteurized Process Cheese Spread (PCS). The Food and Drug Administration (2006) defines process cheese as follows:

> Process cheese is food manufactured by… the mixing of same or two or more varieties of cheese…with an emulsifying agent… with the aid of heat….to produce uniform homogenous plastic mass. (p. 340)

**Factors Impacting the Functionality of Process Cheese**

The process cheese functionality mainly depends on chemical composition and ingredients used in its manufacturing (Kappor & Metzger, 2008). Chemical compositions include moisture content, fat content, intact casein content, whey protein content, lactose content, and total calcium content (Garimella et al, 2006). The difference in the amounts and types of ingredients leads to difference in final composition of the process cheese. Age of natural cheese and type of cheese used in formulation affect the total calcium content and pH of the process cheese (Lee et al., 2003). The emulsifying salt type and amount added to the process cheese affect the emulsification properties of process cheese. The present amount of emulsifying sodium salts in formulation of process cheese is important for good functional property of process cheese. Sodium reduced or sodium replace process cheese with acceptable quality is a tough task.

In addition to the composition and emulsification property, processing condition and parameters of manufacturing process affect the functionality of process cheese (Rayan et al., 1980). Manufacturing parameters such as cooking time and temperature, type and speed of mixing during processing, and rate of cooling are important on the functionality of process cheese (Glenn et al., 2003).

**Reducing Sodium in Processed Cheese**

Process cheese is a blending of natural cheese of different ages, water, optional dairy and non-dairy ingredients, coloring agent and emulsifying salts. More than 90% of the sodium in process cheese comes from natural cheese, emulsifying salts and added sodium chloride (Metzger 2008, Johnson et al., 2009). Emulsifying salts contribute more than 50% of the sodium in some process cheese formulation (Karahadian & Lindsay, 1984). To produce low or reduced sodium process cheese, the level of sodium provided by emulsifying salts and sodium chloride needs to be reduced.

Some researchers followed this method in combination or alone to manufacture an acceptable quality of reduced sodium process cheese. Gupta et al. (1984) described the use of di potassium phosphate and tri potassium citrate for manufacturing processed cheese. Their results showed that di potassium phosphate and tri potassium citrate produced processed cheese with melt-ability and hardness similar to processed cheese manufactured with disodium phosphate and tri sodium citrate, respectively. Metazger and Kapoor (2007) developed a reduced sodium natural cheese that was used as an ingredient in reduced sodium process cheese.

Some studies (Liem et al., 2011; Ley, 2008; McGregor, 2007) show the use of bitterness blockers to block the bitter metallic taste coming from the potassium. Kamleh et al. (2012) conducted a study on the reduction of sodium on Halloumi cheese and checked its effect on cheese quality. From their research data they found that reducing NaCl in Halloumi cheese reduced the saltiness of the cheese and increased bitterness in the product due to addition of KCl. The overall consumer acceptability of cheese was lower.

**Emulsifying Salts**

Emulsifying salt (ES) is an important ingredient in process cheese manufacturing. Emulsifying salt has two main functions in cheese manufacturing process. One is pH adjustment and the second is to break the linkage of phosphate and calcium in added natural cheese source. These two functions of emulsifier help the interaction between the water phase and the oil (fat) phase (Guinee *et al.*, 2004; Mizuno & Lucey, 2005). According to the FDA, the emulsifying salts that could be used for the manufacture of process cheese include one or any mixture of two or more of monosodium phosphate, disodium phosphate, dipotassium phosphate, trisodium phosphate, sodium metaphosphate (sodium hexametaphosphate), sodium acid pyrophosphate, tetrasodium pyrophosphate, sodium aluminum phosphate, sodium citrate, potassium citrate, calcium citrate, sodium tartrate, and sodium potassium tartrate (CFR 21 133.169).

Many researchers have studied the effect of type and amount of emulsifying salt on process cheese manufacturing. Gupta et al., (1984) results show the effect of the amount and type of emulsifying salts on process cheese body, texture, hardness, pH and meltability. Thomas et al. (1973) manufactured process cheese with different emulsifying salts at 3% level and checked the effect of different emulsifying salts on emulsion property and hardness of process cheese. Their research data proved that different emulsifying salts did not have a significant effect on the emulsion property of the final process cheese quality. As a texture and sensory point of view they found significant difference in the final cheese quality made with different type of emulsifying salts.

According to Dimitreli et al. (2005), disodium phosphate, trisodium citrate and sodium tripolyphospahte use as an emulsifying salt provide good emulsification in process cheese. Other side in case of sodium hexametaphosphate when process cheese moisture content increase to 53% and higher shows the water separation in process cheese.

**Microbiology of Process Cheese**

The food product has more than 4.6 pH and greater than 0.85 water activity values has ability develop rapid growth of food borne pathogens. Food borne 1) pathogenic bacteria are listeria monocytogenes, staphylococcus aureus and salmonells species, 2) spoilage bacteria are pseudomonas, and lactobacillus and 3) spoilage molds are penicillium and cladosporium (Linton & Harper, 2008). For storing food, time temperature combination is very important for food safety point of view. Process cheese products are emulsion food, which contains dairy and non-dairy ingredients. Most of the process cheese products have pH between 5.4 to 6.0 and water activity of final products around 0.94 to 0.96 (Cheese and related cheese products CFR 133, 2006). Linton and Harper (2008) studied the survival growth of food borne microorganisms in process and individual wrapped process cheese slices at 5°C and 22°C. From their finding, mold population was decrease at 5°C while increase at 22°C while pathogenic bacteria survival was similar for both storage temperatures.

Addition of salt (NaCl) into food has generally two main purposes, one for taste and second as a preservative. Removal of NaCl means reduce the preservative from the product and reduce the shelf life of the final product. Mostly NaCl replacement in a food product is KCl. KCl mostly alters the taste of food product (Bidlas et al., 2008).

**Chemical Properties of Process Cheese**

Chemical properties of process cheese largely depend on the type of salt and emulsifying salts are added to it during the manufacturing process. Salt is mainly used for preservation and taste purposes in process cheese. Emulsifying salts have an effect on pH, moisture, and protein content of the process cheese. Salt reduction in process cheese affects the stability of pathogenic organism, which causes food poisoning (Reddy & Marth, 1991). The replacement of NaCl with KCl had a significant effect on the chemical composition of cheese (Ayyash & Shah, 2011a). Emulsifying salt had effect on pH change in cheese so process cheese made with different emulsifying salts had effect on water activity, oil separation of process cheese (Awad et al., 2004).

**Process Cheese Texture**

Process cheese texture is an important property as a customer point of view and to differentiate it from other varieties of cheese. Textural properties of process cheese include hardness, gumminess, cohesiveness, chewiness, springiness, brittleness and adhesiveness. Textural and structural property mainly deals with deformation of sample by employing different kind of instruments. Results of small and large deformation test are interpreted to know the effect of different variables like chemical composition, process modification and storage, etc. (Joshi et al., 2004). Emulsifying salts affect the melting and textural properties of pasteurized process cheese. Use of ES increases the pH up to 5.6 to 5.9 in pasteurized process cheese from 5.0 to 5.5 of natural cheese. The increase of pH extent depends on the buffering capacity of cheese, pH of the ES and buffering capacity of ES (Fox et al., 2000). The microstructure, rheology and texture properties of process cheese are greatly influenced by the pH of process cheese (Mulsow et al., 2007). Chewiness, adhesiveness and hardness are the textural property, which can differ in the case when different types of emulsifying salts are used in the cheese manufacturing process (Mizuno & Lucey, 2005). Process cheeses made with potassium chloride (KCl) have a significant effect on textural property of process cheese. Potassium chloride gave very soft and moist texture to the cheese (Kamleh et al., 2012). Emulsifying salts have the ability to change the melting and stretchability property with changing amount and type of emulsifying salt in manufacturing process of process cheese. Sodium chloride (NaCl) is used as a salt source in most of the cheese manufacturing process. Sodium chloride is the ingredient that had a significant effect on the meltability of process cheese. Mozzarella cheese made with partial replacement of NaCl using KCl had a significant effect on cheese meltability. Cheese made with 25% replacement of NaCl using KCl had a more meltability than cheese made with 50% and 75% replacement of NaCl using KCl (Ayyash & Shah, 2011). Mizuno and Lucey (2005) had done study on Pasta Filata cheese using different type and addition rate of emulsifying salts. This study indicated that ES type and amount had a significant effect on meltability and stretchability of cheese texture.

**Process Cheese Sensory**

For continuing consumer interest sensory property of process cheese is very important attribute. Process cheese is mainly produced by blending natural cheeses, water, colorants and emulsifying salts. The blend is heated with continuous mixing until a homogenous consistency achieved (Kappor & Metzger, 2007). A process cheese sensory main factor is taste provided by salt. Salt is one of the prime ingredients, which is responsible for good sensory score and extended shelf-life of process cheese (Liem et al., 2011). One research team made process cheese using KCl instead of NaCl and then evaluated sensory and texture profile analysis (TPA) of the final product. The results showed that KCl gave bitterness, crumbliness and moistness to the product (Kamleh et al., 2012).

Emulsifying salts have an important role to sensory of process cheese. Emulsifying salts gave desirable texture to the process cheese. Reduction of emulsifying salt quantity in process cheese affects the sensory and texture property of process cheese. El- Bakry et al. (2010) research study result data proved that reducing the ES quantity in process cheese increased the processing time and hardness of the imitation cheese. At higher rate of reduction in emulsifying salt quantity around 40% reduction, gave a very hard texture to cheese. Hoffmann et al. (2012) studied the effect of using the potassium based emulsifying salts in cheese manufacturing. At the end of their result they found the use of potassium based emulsifying salts have a significant effect on the sensory quality of process cheese. The process cheese they made had bitter taste and loss of functional property of process cheese. Type of emulsifying salt has marked effect on process cheese spread. Process cheese spread made with a different emulsifying salt have little difference in appearance, spreadability, smoothness, gumminess, and oil separation property while it has significant difference on flavor and stickiness of the process cheese spread quality. Different ES have also effect on chemical composition and microbiological quality of process cheese (El-Shibiny et al., 2007).

# Chapter III: Methodology

This chapter discusses different processing steps such as formulation of raw materials, making process cheese, sensory analysis of process cheese including color, hardness, chewiness, bitterness, saltiness and textural analysis of process cheese including hardness, cohesiveness, springiness, gumminess, and chewiness.

## Formulation of Raw Material

Three different types of process cheese samples were made using the different formulation for the salt and emulsifying salts. The formulation used for the manufacture of process cheese is detailed in Table 1. The salt and emulsifying salts used for different process cheese samples included sodium chloride and potassium chloride and their citrates and phosphates as emulsifying salts.

Techwizard excel program was used to calculate the amount of each ingredient required for process cheese manufacturing. This program was developed by OWL software in Lancaster, Pennsylvania. The level of each ingredients used for process cheese manufacture is described in the following tables for an individual process cheese. The amount of cheddar cheese, anhydrous milk fat, preservatives, acids used for pH adjustment and colorants were the same for all three process cheese samples. The formulation gave the percent weight and amount needed to manufacture each of the three process cheese samples in 10 pound quantities.

The cheese cooker was first washed and dried and then sterilized by heating the water at the 85°C for 15 minutes. At same time the screw of the cheese cooker was also rotated at 300 rpm for sterilization.

Table 1

*Formulation for Process Cheese Samples Using Different Salts (Unit: g)*

| **Ingredients** | **Control** | **Treatment 1** | **Treatment 2** |
|---|---|---|---|
| Cheddar cheese | 4425.0 (88.50 %) | 4425.0 (88.50 %) | 4425.0 (88.50 %) |
| Anhydros milk fat | 141.5 (2.83 %) | 141.5 (2.83 %) | 141.5 (2.83 %) |
| Sodium citrates | 140.0 (2.80 %) | 0.0 (0.00 %) | 70 (1.40 %) |
| Potassium citrates | 0.0 (0.00 %) | 70 (1.40 %) | 0.0 (0.00 %) |
| Dipotassium phosphate | 0.0 (0.00 %) | 70 (1.40 %) | 70 (1.40 %) |
| Sodium chloride | 25.0 (0.50%) | 0.0 (0.00 %) | 12.5 (0.25 %) |
| Potassium chloride | 0.0 (0.00 %) | 25.0 (0.50 %) | 12.5 (0.25 %) |
| Sorbic acid | 10.0 (0.20 %) | 10.0 (0.20 %) | 10.0 (0.20 %) |
| Lactic acid | 7.5 (0.15 %) | 7.5 (0.15 %) | 7.5 (0.15 %) |
| Carotenal | 0.8 (0.02 %) | 0.8 (0.02 %) | 0.8 (0.02 %) |

* Formulation based on making10Lb process cheese

**Manufacture of Process Cheese**

A total of three process cheese samples were made using different formulations as mentioned in above Table 1. The control sample of process cheese was made using NaCl and sodium citrate as an emulsifying salt. The Treatment 1 sample was made using KCl and mixture of potassium citrate and dipotassium phosphate as emulsifying salts. The Treatment 2 sample was made using 50% mixture of NaCl and KCl and same proportion mixture of sodium citrate and dipotassium phosphate as emulsifying salts.

In the first step, ingredients were weighed according to the formulation Table 1. Cheddar cheese (Whitehall Specialties, Whitehall, USA) was weighed and then cut into small cubes.

After cutting the cheddar cheese cubes, they were kept at room temperature for an hour for thawing purpose before using it in process cheese manufacturing. Process cheese cooker (Blentech twin-screw process cheese cooker, Blentech Corporation, Rohnert Park, California) was connected to steam inlet and outlet hoses (2.15 kg/cm$^2$). Once the steam connection finish checked the functionality of pressure release valve for safety purpose an anhydrous milk fat (Mid America Farms, Springfield, Missouri) was added into the cooker. After two minutes of this stage weighed cheddar cheese was added into the cooker and mixed with anhydrous milk fat. This mixture is heated into the cheese cooker until the temperature reached 60°C. Once the mixture temperature reached 60°C, salt (Cargill Inc., Minnesota) and an emulsifying salt (Cargill Inc., Minnesota) was added to the mixture. After five minutes of this addition stage, pH of the mixture was measured by the pH meter (Thermo Electron Corporation, Louisville, Colorado). Lactic acid (BK Giulini cor., Simi Valley, California) was added to the process cheese mixture adjustment of pH to below 5.6. After reaching the mass temperature at 84°C, it was held for five minutes for pasteurization. The purpose of this pasteurization step was to ensure the microbiological safety of process cheese by destroying the enzyme and pathogenic organisms.

Sorbic acid (Chemical supply, Miami, Florida) was added to the process cheese according to the formulation for preservation. For process cheese color, food grade carotenal (International Foodcraft Cor., Linden, New Jersey) was also added. After finishing of this whole manufacturing process, the final process cheese product was packed into 5 pound paperboard loaf boxes (Green Bay Packaging, Green Bay, Wisconsin). Process cheese was stored at 10°C for further analysis.

**Consumer Sensory Test**

Process cheese was analyzed for consumer sensory test. The sensory study was approved by the Institutional Review Board (IRB) at the University of Wisconsin-Stout. The sensory test consisted of three samples; control sample using NaCl and sodium based emulsifying salts, treatment I sample using KCl and potassium based emulsifying salts, treatment II sample using 50.0% mixture of NaCl and KCl and 50.0% mixture of sodium and potassium based emulsifying salts. The cheese samples were evaluated by 66 consumer panels that were willing to participate in sensory evaluation as per their time availability. The consumer panel consisted of university students, faculty and local residents from Menomonie, Wisconsin. For the consumer sensory test process cheese were brought from the refrigerator and cut into one-inch square cubes. Each panel member was provided three cheese samples in 100 mL polystyrene cups coded with three digit random numbers. Each consumer panelist was also provided with a glass of water, a pen and a sensory ballot for evaluation of process cheese samples. The consumer sensory test was conducted at room temperature under normal light conditions. Each panel was asked a series of questions pertaining to color, hardness, saltiness, bitterness and chewiness of each sample. A 9-point hedonic scale was used in the sensory evaluation. The intensity of attributes was quantified on a 1 to 9 scale from none (0), moderate (5) and extreme (9). An example of the score sheet can be found in the Appendix.

**Texture Profile Analysis (TPA)**

Texture profile of cheese sample was measured with the Instron testing machine, Model 3342 (Instron Corp., Norwood, Massachusetts). A TPA test was used for the study of the textural properties of process cheese. Cheese samples were cut into one-inch diameter by two-inch height in cylindrical shape with metal cylinders (25 x 50 mm, dia. x height). For all three types of cheese, four specimens were taken at room temperature. All samples were tested for double compression test and were compressed between two stainless steel 50 mm diameter plates with a load cell of 0.5 kN. Double compression cycle was carried out for the remaining time with the rate of 100 mm/min. All three cheese samples were tested in four replications (3 salt treatments x 4 replications). The test parameters hardness, cohesiveness, chewiness, springiness, gumminess are calculated from the obtained profile using the Bluehill Software (Instron Inc., Norwood, Massachusetts). The maximum force given during the first compression was hardness. The extent to which the sample returns to its original height between two compressions was called springiness. Energy of cheese during second compression in relation to first compression is called cohesiveness. Gumminess is multiplication product of hardness and cohesiveness value. Chewiness is multiplication product of gumminess and springiness (Joshi et al., 2004).

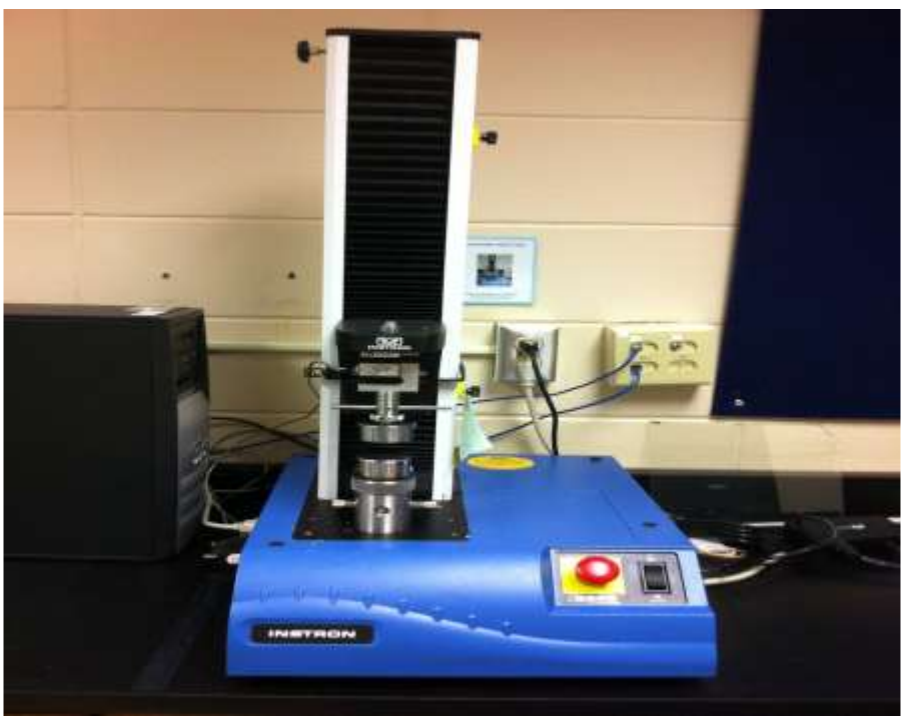


**Figure 1.** Instron texture analyzer used for TPA analysis of process cheese.

**Statistical Analysis**

One-way ANOVA was used to test the difference between three types of process cheeses (Control, Treatment-1, and Treatment-2) completely randomized design experiments data. Level of significance was tested at Turkey's mean difference was 5% ($p \leq 0.05$). This study was conducted using completely randomized design with four replications and different test data was analyzed with SAS Software (version 9 series) by SAS Institute Inc.

# Chapter IV: Results and Discussion

## Effects on Textural Characteristics

To check the effect of different salts and emulsifying salts on textural characteristics of process cheese texture profile were analyzed which includes hardness, cohesiveness, springiness, chewiness and gumminess.

Table 2

*Effect of Types of Salts on Textural Profiles of Process Cheese from TPA Test*

| Texture Profile Attributes | NaCl | KCl | NaCl+KCl | S.E.M. |
|---|---|---|---|---|
| Hardness (N) | 45.27[a] | 37.63[b] | 36.23[b] | 2.28 |
| Cohesiveness | 0.76[a] | 0.80[a] | 0.80[a] | 0.01 |
| Springiness (m x$10^{-3}$) | 3.22[a] | 3.22[a] | 3.22[a] | 0.00 |
| Chewiness (J x$10^{-3}$) | 110.62[a] | 97.14[a] | 94.57[a] | 6.63 |
| Gumminess (N) | 34.32[a] | 30.13[a] | 29.33[a] | 2.06 |

[a,b,c] Means with different letters within the same raw are significantly different ($p \leq 0.05$). S.E.M. is standard error of the means. n = 4.

**Hardness.** The hardness data of all three cheese samples through texture profile analysis were analyzed and arranged in Table 2. Hardness of control sample (NaCl) was 45.27, Treatment 1 (KCl) sample was 37.63, and Treatment 2 (NaCl+KCl) was 36.23. This data showed that control (NaCl) had harder than other two treatments and all three sample's hardness data were found statistically significant (standard error of mean, S.E.M. = 2.28, $p<0.05$). The reason behind this was addition of sodium chloride increase the ionic strength of cheese matrix, which leads to high solubility of protein. High solubility creates swelling of protein strands and as a result protein matrix increase capacity against deformation during compressing, so hardness of cheese with NaCl increases (Pastorino et al., 2003). Kamleh et al. (2012) reported that substitution of NaCl with KCl had a significant effect on hardness of the Halloumi cheese. Ayyash and Shah (2011b) reported that partial replacement of NaCl with KCl had also a significant effect on hardness of the Nabulsi cheese.

**Cohesiveness.** The cohesiveness of process cheese samples data by TPA arranged in Table 2. Cohesiveness of control sample (NaCl) was 0.76, Treatment 1 (KCl) sample was 0.80, and Treatment 2 (NaCl+KCl) was 0.80. After analysis of all three samples, cohesiveness data were not found statistically significant (S.E.M. = 0.01, $p>0.05$). The result of Kamleh et al. (2012) showed that substitution of NaCl with KCl had no significant effect on cohesiveness of the Halloumi cheese. Ayyash and Shah (2011b) indicated that substitution of NaCl with KCl had no significant effect on cohesiveness of the Nabulsi cheese.

**Springiness.** TPA data for springiness of three different process cheese samples were analyzed and plotted in Table 2. Springiness of control sample (NaCl) was 3.22, Treatment 1 sample (KCl) was 3.22, and Treatment 2 sample (NaCl+KCl) was 3.22. This data of chewiness were not statistically significant (S.E.M. = 0.00, $p>0.05$). Katsiari et al (1997) result shows reduction of sodium by partial substitution of NaCl with KCl did not have a significant effect on the springiness of Feta cheese. Ayyash and Shah (2011c) indicated that replacement of NaCl with KCl had no significant effect on springiness of the Halloumi cheese. Katsiari et al (1998) result shows that reduction of sodium by partial substitutuion of NaCl with KCl had no significant effect on springiness of Kefalograviera cheese.

**Chewiness.** Chewiness data of three different process cheese samples were analyzed and plotted in Table 2. Chewiness of control sample (NaCl) was 110.62, Treatment 1 sample (KCl) was 97.14, and Treatment 2 sample (NaCl+KCl) was 94.57. This data of chewiness was not found statistically significant (S.E.M. = 6.63, $p>0.05$). Dimitreli and Thomareis (2007) stated that change in emulsifying salts had no significant effect on chewiness of process cheese. In contrast, Kamleh et al. (2012) result confirmed that substitution of NaCl with KCl had a significant effect on chewiness of the Halloumi cheese.

**Gumminess.** TPA data for gumminess of three different process cheese samples were analyzed and plotted in Table 2. Gumminess of control sample (NaCl) was 34.32, Treatment 1 sample (KCl) was 30.13, and Treatment 2 sample (NaCl+KCl) was 29.33. These data of chewiness were not statistically significant (S.E.M. = 2.06, $p>0.05$). That means there was no significant effect of types of salt used on gumminess in manufacturing of process cheese. Ayyash and Shah (2011b) indicated that substitution of NaCl with KCl had no significant effect on gumminess of the Nabulsi cheese. Katsiari et al. (1997) result shows that reduction of sodium by partial substitution of NaCl with KCl had no significant effect on gumminess of Feta cheese.

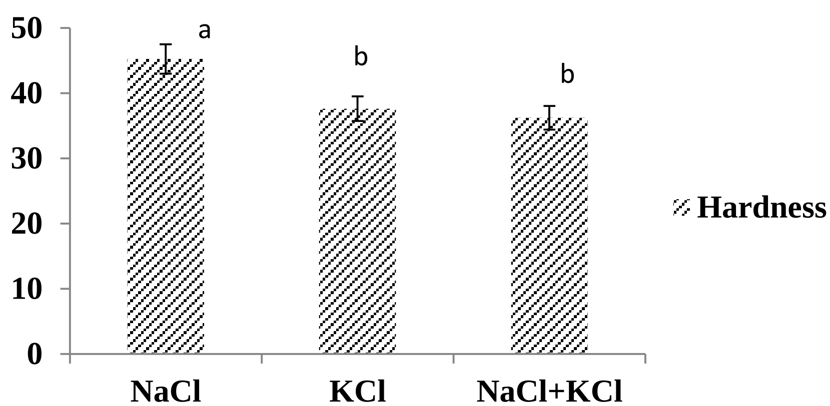


**Figure 2.** Effect of types of salt on the hardness of process cheese by TPA test ([abc] represents the statistical significant difference between treatment)

**Effects on Sensory Characteristics**

Three types of process cheese produced with using different salts and emulsifying salts. All three samples were tested for different sensory characteristics including color, hardness, chewiness, bitterness and saltiness. There were 66 participants in the consumer sensory test. From the 66 participants, 42.42% were male and 57.58% were female. Regarding panelist age 27.27% panelists were between 18-20 years of age, 42.42% were 21-25 years, 19.70% were between 26-30 years, 4.55% were between 31-35 years and the remaining 6.06% were 36 years and above. About panelist cheese eating habits, out of 66 panelists, 30.30% panelists eat cheese on a daily basis, 39.39% eat cheese 2 to 4 times a week, 16.67% eat cheese 2 to 4 times in month, 12.12% eat cheese one time per month and 1.52% panelist mention they never eat cheese. The above data mentions that around 70% of the consumer test panelists were between 18-30 years of age with daily and weekly 2-4 times cheese eating habits.

Table 3

*Effect of Types of Salts on Sensory Characteristics of Process Cheese from Consumer Sensory Test*

| Sensory Attributes | NaCl | KCl | NaCl+KCl | S.E.M. |
|---|---|---|---|---|
| Color | 5.53[a] | 5.36[a] | 5.45[a] | 0.15 |
| Hardness | 4.96[a] | 4.36[b] | 5.06 [a] | 0.20 |
| Chewiness | 4.94[a] | 5.27[a] | 4.95[a] | 0.20 |
| Bitterness | 3.53[c] | 5.38 [a] | 4.67[b] | 0.24 |
| Saltiness | 5.87[a] | 5.32 [b] | 5.22[b] | 0.18 |

[a,b,c] Means with different letters within the same raw are significantly different ($p \leq 0.05$). S.E.M. is standard error of the means. n = 66.

**Color.** Process cheese samples of color data for the consumer sensory test were analyzed and arranged in Table 3. Among 9-point hedonic scales in the sensory evaluation, the intensities of attributes were expressed by none (0), moderate (5) and extreme (9). Result of color content for control (NaCl) was 5.53, treatment 1 (KCl) sample was 5.36, and treatment 2 (NaCl+ KCl) was 5.45. The results for color content of consumer sensory test were not statistically significant (S.E.M. = 0.15, $p > 0.05$). It indicated that consumers could not realize any color difference between different salt treatments compared with normal cheddar cheese made by salt (NaCl). Award et al. (2004) reported that different emulsifying salts mixtures of process cheese were not significant effect on color of process cheese, while Zekai et al. (2004) stated that high NaCl content cheese sample received little higher color score than less NaCl content of cheese sample. Karagozlu et al. (2008) observed that more panelists liked the color of cheese sample that had 100% and 75% of NaCl rather than 100% KCl or 50% mixture of NaCl and KCl.

**Hardness.** The hardness of all cheese samples through consumer sensory test data are shown Table 3. Hardness of control (NaCl) was 4.96 (S.E.M. = ±0.20), treatment 1 (KCl) sample was 4.36 (S.E.M. = ±0.20), and treatment 2 (NaCl+KCl) was 5.06 (S.E.M. = ±0.20). After analysis of all three samples, hardness data for consumer sensory test, treatment -1 (KCl) data was found statistically significant (S.E.M. = 0.20, $p < 0.05$) compare with other two treatments. This analysis indicates that there was a significant effect of types of salts used on hardness of process cheese. Consumers evaluated that KCl treatment cheese had lower score of hardness than samples, which contained NaCl such like control and combined cheese with KCl and NaCl. This sensory result agreed with the result of hardness in TPA which NaCl treatment was harder than KCl treatment. Pastorino et al. (2003) reported that increase in salt (NaCl) content in cheese increase the hardness of the Muenster cheese. Karagozlu et al. (2008) and

Adrino et al. (2011) reported that full and partial substitution of NaCl by KCl gave reduction to hardness of white pickled cheese.

**Chewiness.** Consumer sensory analysis of chewiness data of three different process cheese samples were analyzed and plotted in Table 3. Chewiness of control (NaCl) was 4.94, treatment 1 (KCl) was 5.27, and treatment 2 (NaCl+KCl) was 4.95. The results for chewiness of consumer sensory test were not statistically significant (S.E.M. = 0.20, $p>0.05$). Kamleh et al. (2012) reported that substitution of NaCl with KCl had no effect on chewiness of the Halloumi cheese. El-Shibiny et al. (2007) also demonstrated that different emulsifying salts have no any effect on chewiness of process cheese spreads.

**Bitterness.** The bitterness of all cheese samples through consumer sensory analysis data were arranged in Table 3. According to that table, bitterness of control sample (NaCl) was 3.53, treatment 1 (KCl) sample was 5.38, and treatment 2 (NaCl+KCl) was 4.67. After analysis of all three samples data for consumer sensory test they were statistically found significant (S.E.M. = 0.24, $p<0.05$). This analysis indicates that there was a significant effect of types salts used on the bitterness of process cheese. Process cheese made with KCl had moderate level bitterness on consumer sensory scale (5.38) while cheese made with NaCl had below moderate level bitterness (3.53). That means cheese made from KCl was high bitter in taste than other two salt treatments. Hoffmann et al. (2012) observed that emulsifying salts containing potassium gave bitter taste to process cheese. Karagozlu et al. (2008) reported that full and partial substitution of NaCl by KCl gave bitterness to white pickled cheese and Liem et al. (2011) also confirmed that potassium increase bitterness. To reduce the bitter taste in low sodium process cheese use lower concentration of KCl in cheese manufacturing. Kamleh et al. (2012) suggested that some ingredients such like sucrose, glutamic acid, yeast extract, and caramel solutions contribute to reduce the bitterness of processed cheese made by KCl due to masking effect of those ingredients.

**Saltiness.** The saltiness of three process cheese samples through consumer sensory test data were analyzed and arranged in Table 3. In the consumer sensory test, saltiness of control sample (NaCl) was 5.87, treatment 1 (KCl) sample was 5.32, and treatment 2 (NaCl+KCl) was 5.22. The results of saltiness in processed cheeses with different salt treatment showed statistically significant (S.E.M. = 0.18, $p<0.05$). This data represent that sodium chloride (NaCl) brings more saltiness than potassium chloride (KCl) and consumers were sensitively realized the difference of saltiness between NaCl and KCl treatments even though it had small amount difference. Karahadian and Lindsay (1984) reported that full sodium cheese was more salty than reduced sodium process American cheese. Liem et al. (2011) and Kamleh, et al. (2012) also confirmed that KCl reduced saltiness in the processed cheeses compared with NaCl treatment.

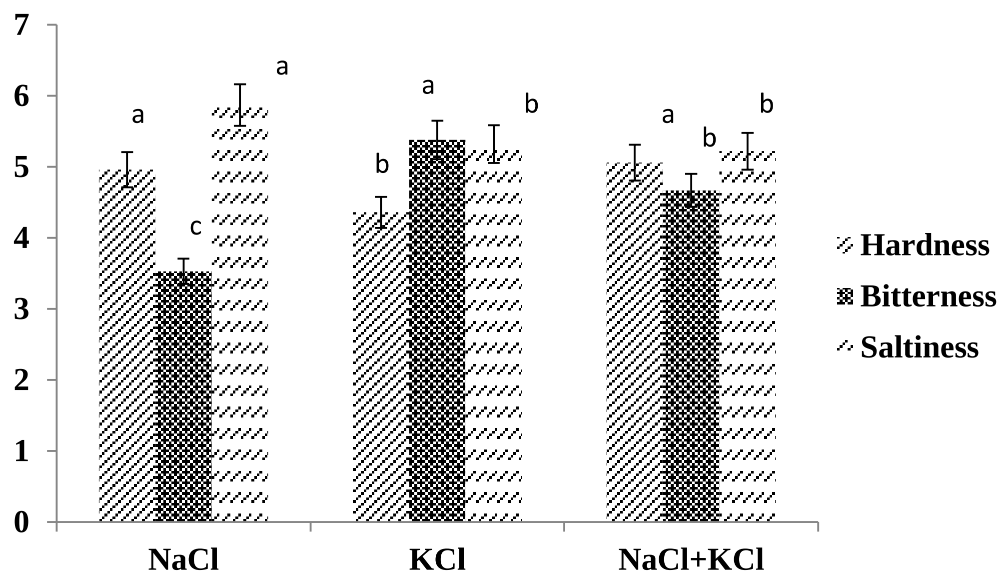


**Figure 3.** Effect of types of salt on the hardness, bitterness, and saltiness of process cheese by consumer sensory test. ([abc] represents the statistical significant difference between treatment)

# Chapter V: Conclusion

To reduce sodium consumption in processed cheese, potassium chloride (KCl) was tested as a salt (NaCl) replacer. Texture profile analysis (TPA) and sensory evaluation were determined with different salt treatments of the process cheese. To compare with control (NaCl) treatment, KCl did not changes of product color and textures such as cohesiveness, springiness, chewiness and gumminess. However, KCl had a significant effect on hardness of process cheese in both of TPA and sensory test. Consumers realized that KCl treatment was softer than NaCl treatment and TPA results also supported this sensory result. More serious limitations to use KCl as NaCl replacer came from high bitterness and low saltiness of KCl treatment. Therefore, the results of this study recommended that combination of NaCl and KCl have more effective to reduce sodium contents with minimum changes of bitterness, saltiness and texture profiles to compare with single usage of KCl in the process cheese.

## Recommendation for Further Study

It will be important to do further study on the process cheese with using ingredients that can mask the bitterness of the product because it can improve the acceptability of the process cheese with KCl and potassium base emulsifying salts. It would be interesting to study the effect of KCl on sensory of process cheese at lower concentration and also recommended for future research to use other sources of salt replacer than KCl in process cheese.

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# Appendix

Sensory Ballot Used to Evaluate Sensory Attributes of Pasteurized Process Cheese

*Processed Cheese*

Please rinse your mouth with water before starting. There are three samples of Processed cheese in a tray for you to evaluate. For evaluation, place sample in your mouth and take two bytes of it. Rate the sample for the following attributes on the scales below. Circle the number that indicates the intensity of the attribute. Please rinse your mouth with water between each sample.

Sample #:

Color
1 2 3 4 5 6 7 8 9
None Moderate Extreme

Hardness
1 2 3 4 5 6 7 8 9
None Moderate Extreme

Saltiness
1 2 3 4 5 6 7 8 9
None Moderate Extreme

Bitterness
1 2 3 4 5 6 7 8 9
None Moderate Extreme

Chewiness
1 2 3 4 5 6 7 8 9
None Moderate Extreme

Sample #:

Color
1 2 3 4 5 6 7 8 9
None Moderate Extreme

Hardness
1 2 3 4 5 6 7 8 9
None Moderate Extreme

Saltiness
1 2 3 4 5 6 7 8 9
None Moderate Extreme

Bitterness
1 2 3 4 5 6 7 8 9
None Moderate Extreme

Chewiness
1 2 3 4 5 6 7 8 9
None Moderate Extreme

Sample #

Color

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| None | | | | Moderate | | | | Extreme |

Hardness

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| None | | | | Moderate | | | | Extreme |

Saltiness

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| None | | | | Moderate | | | | Extreme |

Bitterness

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| None | | | | Moderate | | | | Extreme |

Chewiness

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| None | | | | Moderate | | | | Extreme |

Consumer Questions:

Please answer every question and check only one response per question.

How often do you Eat Processed cheese?

Daily 2-4 times a week 2-4 times a month less than once a month Never

What is your gender?

Male Female

What is your age?

18-20 years 21-25 years 26-30 years 31-35 years 36 and older