

ABSTRACT

DIXON, ELIZABETH MARIE. Whey Permeate, Delactosed Permeate, and Delactosed Whey as Ingredients to Lower Sodium Content of Cream Based Soups. (Under the direction of Jonathan C. Allen)

The use of whey permeates as salt substitutes can help to decrease sodium and chloride intake, increase potassium, calcium and magnesium intakes and decrease hypertension risk. Five different whey permeates from 5 different manufacturers were analyzed with ICP for mineral content (Na, K, Ca, Mg, Fe, Zn). Two permeates are powder and three are liquid. Lactose and protein content were also analyzed by Lactose/D-Glucose UV kit from Roche and BCA protein assay, respectively. Chloride and phosphate were measured spectrophotometrically. Basic tastes and aromas were quantified by a trained sensory panel. Based on the highest “salty taste” identified by the trained sensory panel, one liquid and one solid permeate were further investigated as sodium substitutes. The sodium content of the guideline solutions for comparing salty taste of the permeates were used to calculate the equivalent concentrations of salt and permeate for salty taste in aqueous solution. Two soup formulations were used to test the use of permeate as a salt substitute; one retorted, canned, condensed cream soup base, and one fresh cream soup base. Each formulation of soup was tested on a separate day by 75 consumer panelists who averaged between 20 and 30 years of age. Four samples were given each day 0%, 50%, 100% of the standard salt content in condensed soup, and permeate at a content calculated to be equal in salty taste to the standard salt content. The permeate soup was ranked in salty taste slightly lower than the 50% sample

for the fresh soup. In the retorted soups, the permeate was ranked slightly higher than the 50% sample. However, the fresh and retorted soup formulations made from permeate actually contained 11% and 19% as much sodium as the full-salt recipe, respectively. The permeate soup was described as higher in salty taste than expected based on actual sodium content, but not as high as predicted from the salty taste of the permeate in aqueous solution. Potassium and magnesium levels were increased in the formulations with permeate. This research gives an optimistic view on the possibility of whey permeates and their capability of replacing sodium in cream soups and other processed foods.

Whey Permeate, Delactosed Permeate, and Delactosed Whey as Ingredients to Lower
Sodium Content of Cream Based Soups

by
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DEDICATION

To my loving parents, family, and friends who have been there to support me throughout my educational career and through what is still to come.

BIOGRAPHY

Elizabeth Marie Dixon was born on April 4th, 1984. Her father was in the military and retired his family in Goldsboro, NC in 1992. She went to Eastern Wayne High school and graduated in the spring 2002. She started her college career at North Carolina State University during the fall of 2002. Originally wanting to become an ophthalmologist, she soon realized her passion for nutrition. She took classes at both NCSU and Meredith College to fulfill the didactic program in dietetics. Aspiring to become a registered dietitian she acquired an internship at East Carolina University in the fall of 2008. She worked for Dr. Jonathan C. Allen in his food and nutrition laboratory for four years as an undergraduate, and appreciates all she has learned from her experience working with the graduate students and research technicians in the laboratory. She was an active member of the Food Science Club and worked closely with the outreach committee to work with elementary students around the county. She is excited to see what is in store in the future for her.

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CHAPTER 1

Review of Literature

Hypertension

People who are affected by hypertension have a blood pressure greater than 140/90 mm Hg (Miller, 2003). Due to high sodium intakes and other factors in the United States, about 65 million adults are considered to be hypertensive (Bosworth, 2007). Hypertension is considered one of the most common chronic diseases in the US (USDA, 2005). Only one-third of the hypertensive population in the US has effective control over their blood pressure (Bosworth, 2008).

Sodium can be found in many sources in the diet. The current USDA guidelines (2005), suggest consuming less processed foods and consuming more potassium rich foods to help decrease salt intake in the diet. For example canned soups contain almost half of a daily serving of sodium with 700-1260 mg sodium per eight ounces of soup (USDA, 2005). American diets obtain most of their sodium (~75%) from processed foods like these (USDA, 2005).

Sodium Intake in United States

The dietary guidelines currently suggest a maximum intake of 2300 mg of sodium per day (USDA, 2005). The current mean intake for the people with high blood pressure and with normal blood pressure is 3330 and 3600 mg per day, respectively (Ajani, 2005). Others have found similar results with current mean intake for the US being 3,380 mg/day (Johnson

and Kumanyika, 2008). The average discretionary intake of sodium contributes to 5-10% of total salt intake in the diet (USDA, 2005). Discretionary intake is the amount of salt that is added to food from a salt shaker at the dinner table. Naturally occurring sources of sodium only make up for about 10% of sodium within the diet (Johnson and Kumanyika, 2008).

Some implications of high dietary salt intake include increases in body water weight, total exchangeable sodium, extracellular fluid volume, and plasma volume (USDA, 2005), all of which contribute to hypertension (Haddy, 2006). Hunt (1998) reported that reducing diastolic blood pressure by 2 mm Hg can reduce the risk for hypertension by 17%, based on analyses from Framingham Heart Study and NHANES II research data. Unfortunately, if this disease is left untreated it could lead to disability or death due to stroke, heart failure, and kidney failure (Haddy, 2006).

The degree to which the sodium ion is responsible for increases in blood pressure is controversial. Animal studies comparing multiple forms of sodium with sodium chloride show the real cause may be the chloride ion. Blood pressures tended to fall with the reduction of sodium chloride and not with other forms of sodium from the diet (Kaplan, 1985). Most sodium added to our foods is in the form of sodium chloride; the reduction of sodium within the diet will usually result in simultaneous reduction of chloride.

High Risk Populations

It has been estimated that about half of the people diagnosed with hypertension are considered salt-sensitive (Haddy, 2006). Salt sensitivity is the propensity for increases of

sodium within the diet to increase blood pressure (Antinoro, 2007). People with salt sensitivity tend to develop hypertension with an intake of 125 to 250 mmol (2875 to 5750 mg) of sodium per day (Brody, 1999). People without salt sensitivity may not begin to have a rise in their blood pressure with the intake of up to 300 mmol (6900 mg) of sodium per day (Brody, 1999).

African America Population

There is growing concern for the large disproportionate incidence of hypertension between African American and Caucasian hypertensive patients. The African American population of the US develops more cardiovascular cases than white subjects and any other population in the world (Bosworth, 2008; Karanja et al., 2007). Obesity, higher prevalence of salt-sensitivity and physical inactivity among African Americans are possible factors for the elevated risk for hypertension (Calpurnya et al., 2007). It is possible that this lifestyle is why high blood pressure is prevalent in earlier stages in life in this ethnic group. Socioeconomic status and access to quality health care are also other factors in hypertension prevention (Roberts et al., 2007). Traditional African American foods are often high in salt, such as pork that is traditionally salted as a method of preservation (Smith et al., 2006).

The Trials of Hypertension Prevention II, may provide insight as to why African Americans tend to suffer from a higher risk of hypertension. This study found a large number of participants of African American race having AA genotype and a very low percent having GG genotype form (Hunt, 1998). This study, further explained below, shows

populations with AA form of angiotensinogen gene are more likely to be sensitive to sodium (Hunt, 1998). This gives a reason to believe that African Americans who are consuming high sodium diets may be at higher risk due to their genetic sensitivity to sodium.

Elderly Population

The older populations of the US are also considered higher risk for hypertension. An estimated 70% of the adults over the age of 65 are considered to have elevated blood pressure (Antinoro, 2007). Low plasma renin tends to be the main cause of hypertension in this population (Haddy, 2006). Plasma renin is a peptidase that is synthesized and secreted by cells in the arterioles entering the glomerulus in the kidneys (Brody, 1999). Renin helps to control the sodium-potassium balance, fluid volume and blood pressure in the body (Haddy, 2006). With low renin activity, the body tends to decrease the excretion rate of sodium from the body.

Decrease in taste sensation may also be a reason many elderly people consume higher amounts of sodium, and thus have higher blood pressure. One study suggests altered ability to discriminate between flavor intensities of suprathreshold taste stimuli may be why older adults increase sodium intake (Nordin et al., 2003; Smith et al., 2005). In another study, 15 men and 15 women between the ages of 65-78 years of age were recruited to represent the “elderly” population, while 15 men and 15 women 18-25 years were representative of the “young” population. Participants tasted 30 samples of randomized sodium chloride

intensities and were asked to identify the strongest taste (Nordin et al., 2003). Researchers used the Weber ratio (WR) to analyze the data. “WR is the minimum noticeable difference to the stimulus intensity” (Nordin et al., 2003).

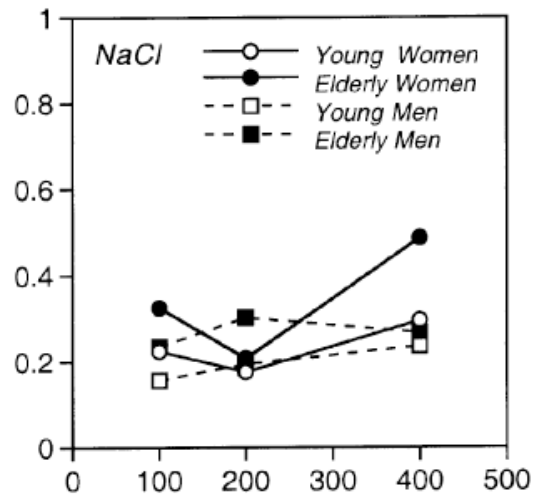


Figure 1: Weber Ratio (y-axis) and mmol Concentration of NaCl (x-axis) (Nordin et al., 2003)

As shown in figure 1, there was a large difference between the elderly population and the younger population. Overall, the elderly population had the largest WR, suggesting much poorer intensity discrimination in older subjects (Nordin et al., 2003). Also, they found there was a larger effect for size for males than for females (Nordin et al., 2003). This relatively small study shows how the elderly population can be at a higher risk for elevated blood pressure due to decreased taste discrimination.

Barriers to Dietary Treatment

It has been shown that up to 60% of hypertensive people generally stop treatment within the first year of care (Bosworth, 2008). This may be due to many barriers patients may have to face dealing with hypertension. For example, patient complaints of acceptability of reduced sodium diets due to their perceived low palatability (Malherbe, 2003; Blais et al., 1986). There is also a low selection of low sodium options for many products (Karanja et al., 2007). Palatability and compliance for low sodium diet is further discussed later.

Another barrier may be how salt is viewed in different cultures. The south is historically known for the consumption of highly salted foods such as cured pork (Smith et al., 2006). Salt is traditionally seen as a flavor enhancer and secondarily as a preservation method (Smith et al., 2006). This perception is partly why salt is so difficult to reduce or exclude from the diet. Many elderly participants of one study repeatedly expressed the need for “fresh” vegetables to have added salt during food preparation. Many of the minority women discussed the need to decrease the “bland” or “fresh” flavor out of vegetables by adding salt (Smith et al., 2006).

Misunderstandings regarding salt consumption can also be a barrier for reduction of salt in the diet. Smith et al., (2006) found many of the elderly participants believed salt added during the cooking process is “healthier” for you than when added at the dinner table. Participants believed that the salt added at the table, “raw” salt, contains unhealthy impurities that are not cooked out during preparation (Smith et al., 2006). Because many physicians are

unaware of these beliefs, these behaviors are classified as “noncompliant” to low sodium diets (Smith et al., 2006). Physicians gaining more knowledge of the patients’ culture and traditions may help them consult lower sodium diet.

FDA Labeling Rules

The government has allotted many rules for labeling sodium on food products. According to the Food and Drug Administration, the term “healthy” can be stated on the food label only if the food contains no more than 480 mg of sodium per serving for the individual foods (Stehlin, 1993). There should be no more than 600 mg for meals and main dishes (Stehlin, 1993). “Low Sodium” should have not more than 140 mg or less than the reference food (Stehlin, 1993). For meals and main dishes, there should be no more than 140 mg per 100 grams of meal or main dish. For “reduced or less” sodium labeling, there should be at least 25% less sodium than the reference food, when the reference food is not considered a “low sodium” food (Stehlin, 1993).

Dietary Approaches to Stop Hypertension (DASH)

One of the most notable studies that involved a major dietary intervention was the Dietary Approaches to Stop Hypertension study (DASH). This study showed the relationship dietary effect of sodium amongst other factors on blood pressure, and possible risk of hypertension through diet. The main focus for this paper is the DASH sodium trial.

The primary aim of this study was to “determine the effect on blood pressure of three levels of dietary sodium in the usual US diet” (Champagne, 2006). The second aim was to find the “effect on blood pressure of the DASH diet with three levels of dietary sodium” (Champagne, 2006). This study also wanted to see how the reduction of sodium compared with the two different diets and how the varying levels of sodium affect blood pressure (Champagne, 2006).

The “usual” American diet was described as a high fat content with 37% of the daily calorie intake per day coming from fat (Champagne, 2006). The fat was mainly saturated fats (16% of total calorie intake) (Champagne, 2006). Protein and carbohydrates made up of 15% and 48% of total calories, respectively (Champagne, 2006). The diet also had a low fiber content of 9 grams, and low potassium, magnesium and calcium content at 1700 mg, 165 mg, and 450 mg per day, respectively (Champagne, 2006). Sodium in this diet ranged from 3 to 3.5 g/day.

In contrast, the DASH diet had a lower fat content of 27% of total calories per day (Champagne, 2006). The fat percentage may not have been a large decrease; the main focus was on the type of fat within the diet. The fat in the DASH diet was predominantly unsaturated fat and only had about 6% of total calories from saturated fat (Champagne, 2006). Protein and carbohydrates were 18% and 55%, respectively (Champagne, 2006). The fiber was increased to about the recommended intake of 31 grams per day (Champagne, 2006). Mineral content was also increased to be around the recommended intake of 4700 mg

of potassium, 500 mg magnesium, and 1240 mg of calcium (Champagne, 2006). The protein and calcium in this diet mainly came from dairy products (Champagne, 2006).

The groups for this study were randomly assigned and placed into 2 different dietary pattern groups: DASH diet and the usual American diet. The diet within each dietary pattern group was randomly changed for 3-week intervals to high, intermediate, or low sodium levels, which actually averages about 4450, 3000 and 1400 mg Na per day (Harsha et al., 2004). This helped to show the effectiveness of sodium with varying levels of intake. Overall, there were about 412 participants, 56% of them being women (Champagne, 2006) and 56% were African American. The mean age of this group was 49 kg/m², and the average body mass index was 29 kg/m², which is considered to be overweight (Champagne, 2006). Overall, 41% of the participants in this study were hypertensive (Champagne, 2006).

As shown in figure 2, the results showed that there was an overall decrease in blood pressure of all groups. The difference between the DASH and American diet groups' blood pressure was greater for people consuming high and intermediate sodium levels (Champagne, 2006). Within each dietary pattern, lowering sodium intake produced slight reductions in blood pressure. Greatest effects were shown with older individuals and the combination of DASH diet and sodium reduction (Champagne, 2006). This report shows that factors in the DASH diet other than sodium level help to lower blood pressure.

Table 2. Blood Pressure Changes in the Dietary Interventions to Stop Hypertension (DASH) Sodium Trial (adapted from Sacks et al., 2001³)

DASH vs Average American Diet (Comparison Diet)	Blood Pressure	
	Systolic	Diastolic
	<i>Mean mmHg (95% CI)</i>	
High sodium level	-5.9 (-8.0 to -3.7)***	-2.9 (-4.3 to -1.5)***
Intermediate sodium level	-5.0 (-7.6 to -2.5)***	-2.5 (-4.1 to -0.8)**
Low sodium level	-2.2 (-4.4 to -0.1)*	-1.0 (-2.5 to 0.4)
DASH diet		
Change from high to intermediate sodium	-1.3 (-2.6 to 0.0)*	-0.6 (-1.5 to 0.2)
Change from intermediate to low sodium	-1.7 (-3.0 to -0.4)**	-1.0 (-1.9 to -0.1)**
Average American at high sodium (comparison diet)		
Change from high to intermediate sodium	-2.1 (-3.4 to -0.8)***	-1.1 (-1.9 to -0.2)**
Change from intermediate to low sodium	-4.6 (-5.9 to -3.2)***	-2.4 (-3.3 to -1.5)***

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Figure 2: Blood Pressure Changes in DASH Sodium Trial (Champagne, 2006)

Trials of Hypertension Prevention I (TOHP I)

Another study that helped to show the need for reduction of sodium was the Trials of Hypertension Prevention. The first trial primarily aimed for the “feasibility and efficacy of seven non-pharmacological interventions in reducing blood pressure of people with high to normal levels” (Cook et al., 2007). With this study, the main focus was on the sodium intervention group.

Participants were chosen based on their age and blood pressure; 30-54 years and mean diastolic pressure of 80-89 mm Hg (Cook et al., 2007). Participants could not be using antihypertensive medication. Overall, from 9 different clinical centers, there were 417 participants in the sodium intervention group (Cook et al., 2007).

The study lasted 18 months with two major groups, the sodium intervention group and the usual care group (Cook et al., 2007). The sodium intervention group received dietary

and behavior counseling on how to identify sodium in the diet. They also self monitored their sodium intake, and selected and prepared foods that are lower in sodium. For the first three months, there were individual and weekly group counseling sessions. After the first three months, supplementary counseling was offered for additional support (Cook et al., 2007). The results of this study showed there was a reduction in hypertensive risk by significantly decreased systolic and diastolic pressures of 1.7 and 0.8, respectively (Cook et al., 2007; Kumanyika et al., 1993). These numbers were small changes, but since this was a large scale study, it still suggests that hypertension can be decreased with a reduction in sodium intake (Cook et al., 2007).

Trials of Hypertension Prevention II (TOPH II)

A secondary study, TOPH II, further explored the effectiveness of sodium reduction, weight loss and a combination of the two (Hunt, 1998). Men and women between the ages of 30 and 54 years of age were recruited for this three-year study. Qualified participants were moderately overweight, being 110% to 160% over desirable body weight, and were pre-hypertensive, with blood pressure between 83-89 mm Hg (average over 3 baseline visits) (Hunt, 1998). Overall, 2382 participants were recruited and were divided into four different groups; sodium reduction, weight reduction, combination group and a usual care (control) group (Hunt, 1998). Focusing on the sodium reduction participants, a dietary goal intake of < 80 mmol/d was the target in this intervention group (Hunt, 1998).

A different approach for hypertension risk was also researched in this study. Angiotensinogen genotyping was also looked at to see any differences between participants. Angiotensinogen can be found in many blood pressure regulating tissues, such as kidneys and brain tissue (Hunt, 1998). A prohormone, angiotensinogen, is cleaved by rennin to form angiotensin I (Brody, 1999). Blood pressure is partly regulated by the concentration of angiotensinogen within the body. The amount of aniotensinogen produced by the body is a factor in how well the body is able to regulate sodium levels. Antibodies that act against angiotensinogen decrease blood pressure (Hunt, 1998).

Two A and G nucleotide substitutions, near the promoter region of the angiotensinogen gene, may interact with the binding of nuclear proteins and thus cause gene transcription to increase angiotensinogen levels (Hunt, 1998). Obtaining genotypes from all patients helped to determine the relation of angiotensinogen genotype and hypertension.

Over the three year study there was some evidence of sodium sensitivity to participants with AA genotype. Those with GG genotype seemed to show resistance to the sodium reduction. There was a temporary decrease in blood pressure within the first 18 months, but at the 36 month point, blood pressures for the GG genotype group, seemed to return to levels similar to the usual care group's (Hunt, 1998). The downside to this study was the fact that the only participants analyzed for genetic relationships for hypertension were Caucasian. This is due to the low amount of variation (3%) of the 323 African American participants, who predominantly had the GG genotype (Hunt, 1998). With further

research, genotyping could prove the key to unlocking the mystery as to why African Americans are at higher risk for hypertension.

TABLE 5. Adjusted Net Effect of Sodium Reduction on Blood Pressure Change (\pm SE) Among White Subjects: TOHP, Phase II*

	AA	AG	GG	Trend <i>P</i>
Change in DBP				
6 mo	-1.0 \pm 1.1	-1.3 \pm 0.7	-1.5 \pm 0.8	0.73
18 mo	-2.2 \pm 1.0	-1.2 \pm 0.7	-0.6 \pm 0.8	0.18
36 mo	-2.2 \pm 1.1	-0.7 \pm 0.7	1.1 \pm 0.9	0.01
Change in SBP				
6 mo	-2.3 \pm 1.4	-2.6 \pm 0.9	-2.7 \pm 1.1	0.81
18 mo	-2.5 \pm 1.2	-1.0 \pm 0.8	-2.2 \pm 0.9	0.89
36 mo	-2.7 \pm 1.4	-1.3 \pm 0.9	-0.2 \pm 1.1	0.17
Change in sodium, mmol/24 h				
6 mo	-90 \pm 21	-58 \pm 14	-57 \pm 17	0.25
18 mo	-48 \pm 12	-48 \pm 8	-62 \pm 9	0.38
36 mo	-53 \pm 12	-45 \pm 8	-45 \pm 9	0.55

DBP indicates diastolic blood pressure; SBP, systolic blood pressure.

*Change in blood pressure calculated by change in sodium reduction group minus change in usual care group adjusted for age, gender, and baseline level of the variable.

Figure 3: Adjusted Net Effect of sodium Reduction on Blood Pressure Change Among White Subjects (Hunt, 1998)

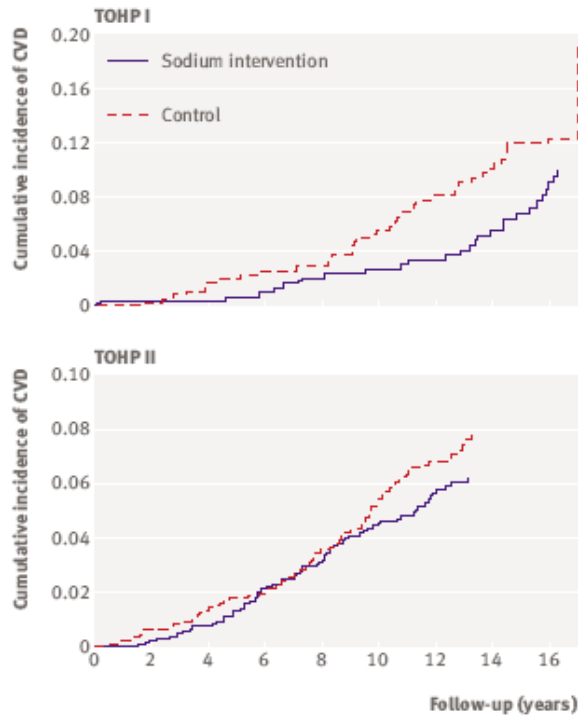


Fig 2 | Cumulative incidence of cardiovascular disease (CVD) by sodium intervention group in TOHP I and II, adjusted for age, sex, and clinic

Figure 4: TOHP I and TOHP II incidence of cardiovascular disease by sodium intervention group (Cook et al., 2007)

Palatability of Low Sodium Diets

Low sodium diets are known to be bland, tasteless and boring in flavor (Malherbe, 2003; Blais et al., 1986). Due to this common knowledge, many companies are trying to change their formulations or do not bother at all with lower sodium food because they do not taste as well as the originals (Malherbe, 2003).

Consumer acceptance research in foods with lower sodium content found some foods can be reduced from 30% to 50% without affecting acceptance and taste of the food (Adams and Maller, 1995). This research was carried out in 2 phases. The first studied the consumers' idea of saltiness and acceptability of "regular" and "low sodium" entrees. In the second phase, "foods were systematically reduced in sodium content and rated to see if specific foods influence both the perception of saltiness and acceptability" (Adams and Maller, 1995). The first phase results indicated that the complexity of the food may impact how we perceive saltiness. It may be the interaction of the other ingredients, such as fats and spices that cause us to perceive saltiness differences even when actual sodium content did not vary by a large degree. This particular phase of the study found that salt in food could be reduced by 50% or more, but acceptability and saltiness were specific to the entrée (Adams and Maller, 1995).

In phase two, results further supported the idea of food being the carrier for saltiness, but the complexity of food is what caused perception of the different levels of saltiness. The simpler the food item, the more salty the food was perceived (Adams and Maller, 1995). Salt is often added to different foods to help enhance flavors. For example, salt added to acidic foods have been shown to increase palatability (DeSimone and Lyall, 2006).

Table 4
Effect of sodium concentrations on saltiness and acceptability ratings of commercially prepared foods

Food item and % sodium	Saltiness			Acceptability		
	Mean ^a	SD ^b	Significant difference ^c	Mean	SD	Significant difference
Breads						
<i>Whole wheat</i>						
regular—0.60	3.2	1.6	y	6.0	1.7	NS ^d
low sodium—0.05	2.1	1.4	x	6.1	1.4	NS
<i>Oatmeal</i>						
regular—0.49	2.7	1.6	xy	6.2	1.0	NS
low sodium—0.06	2.0	1.2	x	6.7	1.0	NS
Snacks						
<i>Potato chips</i>						
regular—0.16	4.1	1.6	y	5.9	1.9	NS
low sodium—0.01	1.8	0.8	x	5.7	1.3	NS
<i>Tortilla chips</i>						
regular—0.43	5.1	1.6	z	5.5	1.3	NS
low sodium—0.01	1.8	1.1	x	5.5	2.4	NS
Vegetable juices						
<i>Vegetable juice</i>						
0.03	3.2	1.6	x	3.7	1.6	x
0.25	3.0	1.4	x	6.3	1.7	y
0.37	4.2	1.8	xy	5.6	1.6	y
0.60	4.9	1.7	y	6.7	1.4	y
<i>Tomato juice</i>						
0.01	2.9	1.8	x	2.5	1.3	x
0.25	3.5	1.9	x	5.0	2.1	y
0.37	4.5	1.8	xy	4.9	2.2	y
0.60	5.3	1.8	y	6.1	1.9	y

^a9 = very salty and like extremely; 1 = low salt and dislike extremely; 0 = not at all salty.

^bSD = standard deviation.

^cMean values with different letter designations are significantly different at $P < .01$.

^dNS = not significant.

Figure 5: Effect of sodium concentrations on saltiness and acceptability ratings of commercially prepared foods (Adams and Maller, 1995)

Physiology of Salty Taste

Understanding how bodies perceive the basic taste of salt may be key to understanding why they permeate may be able to mimic sodium chloride. According to DeSimone and Lyall (2006), stimuli to salty taste have been shown to be learned in humans and laboratory rats postnatally. This suggests from birth, environment and our exposure to different foods help to form our perception of salty stimuli and threshold. The detection of

salt is an important sense for humans and many other animals for water homeostasis and electrolyte balance within the body (Bigiani et al., 2003)

With salty taste, cation channels receive an influx of Na^+ which causes depolarization (Sugita, 2006). Evidence suggests the epithelial-sodium channel (ENaC) is the mammalian Na^+ specific taste receptor (DeSimone and Lyall, 2006). This influx thus causes an influx of action potentials resulting in membrane depolarization, neurotransmitter release onto the afferent nerve, and activation of voltage gated Na and Ca^{2+} channels (Sugita, 2006).

The chorda tympani taste nerve has been pharmacologically dissected into amiloride-sensitive and amiloride-insensitive sections (Sugita, 2006). In rat studies, the chorda tympani nerve holds the ability for a rat to discriminate between NaCl and KCl. N-fibers are associated with Na^+ salts and are amiloride-sensitive. It has been shown that most mammals also have one or more salt taste receptors that are nonselective to cations (Desimone and Lyall, 2006). These are the H-fibers which are linked with the amiloride-insensitive responses whereby KCl and NH_4Cl responses are perceived as salty (Sugita, 2006; DeSimone and Lyall, 2006). Activation of these fibers may be the methods as to how salt substitutes and whey permeate are able to elicit a salty response without containing sodium chloride.

Potassium salts are found to be a large part of whey permeate (Allen et al., 2002). Current research suggests that the K^+ can leak through tight junctions of amiloride-insensitive epithelial cells on the apical membrane of the taste buds (Bigiani et al., 2003). An influx of K^+ ions causes a depolarization of the basolateral membrane, which then gives an

activation of taste receptor cells (Bigiani et al., 2003). This cellular signal sends an action potential to nerve fibers that elicits the salty-bitter taste associated with potassium (Bigiani et al., 2003).

Current Industrial Methods of Sodium Chloride Replacement

Currently there is little research on the use of whey permeates and sodium reduction. Since there is high potassium to sodium ratio (Marjanna et al., 2002), the minerals in whey permeates could play a role in increasing perceived sodium taste from foods.

There is growing interest in sodium reduction and industry has implemented several ways to meet consumer demands for a reduced sodium product. Potassium chloride is often used as a partial sodium substitute (Desmond, 2006). This technique has been shown to have an undesirable bitterness when formulations exceed 50:50 blends of sodium chloride and potassium chloride (Desmond, 2006). The bitterness perceived can be reduced with masking agents such as yeast extracts. There are some products that block the bitter taste perceived with the potassium-chloride products. AMP (5'-adenosine monophosphate), has been found to block the activation of gustducin, a G-protein that is found in taste receptor cells. Preventing the stimulation of this G-protein prevents the nerve stimulation, thus blocking the bitter taste (Desmond, 2006).

Some products have been shown to successfully incorporate potassium chloride as a partial substitution for sodium chloride. Fish sauce, which is widely used in Southeast Asia, contains a high amount of salt. Generally fish sauce is produced by mixing the fish in a 2:1

or 3:1 fish to salt ratio (Sanceda, N. et al., 2002). This mixture is allowed to ferment for 12 months, afterwards the liquid is collected. In one study on fish sauce, sodium chloride was mixed with potassium chloride in ratios of 90:10, 75:25, and 60:40 (Sanceda et al., 2002). Participants were screened for diets that usually contained fish sauce, and were asked for liking and acceptability with each sample (Sanceda et al., 2002).

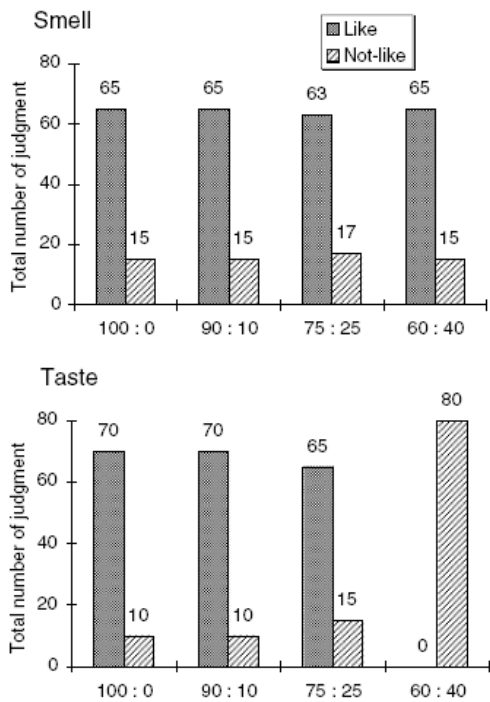


Figure 3 Liking and disliking of the smell and taste of NaCl : KCl fish sauces.

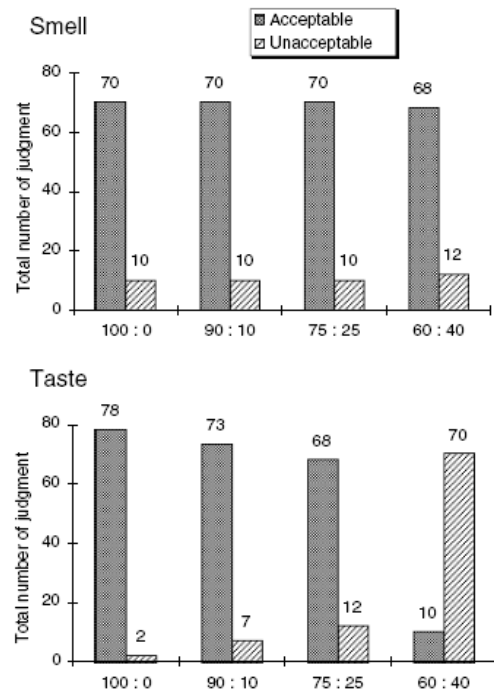


Figure 4 Acceptability of the smell and taste of NaCl : KCl fish sauces.

Figure 6: Liking and acceptance of fish sauces with partial substitution of sodium chloride with potassium chloride (Sanceda et al., 2002).

As shown in figure 6, liking was not significantly different between any of the samples, except for the 60:40 sodium chloride/potassium chloride. There was total rejection of the 60:40 ratio, shown on figure 6 mainly due to the bitter taste brought out by the high potassium chloride concentration (Sanceda et al., 2002). This study was able to show a 25% partial substitution with potassium chloride for sodium chloride in a sauce without affecting liking or acceptance. With higher substitution with potassium chloride, the sauce was deemed unacceptable by consumers.

There are many versions of potassium chloride mixed salts that are available commercially for consumers. For example, the Morton Company produces a product called Lite Salt®. This mixture contains a 1:1 wt/wt ratio of sodium chloride and potassium chloride (Karahadian and Lindsay, 1984). Salt in cheese has a role in the development of flavor, texture, and controlling the microbial and enzymatic processes in cheese ripening (Karahadian and Lindsay, 1984). Research on cheeses that had reduced sodium chloride content was found to have an “unpleasant chemical-like” flavor (Karahadian and Lindsay, 1984). One study evaluated the use of Lite Salt® in cheddar cheeses to reduce sodium to 55% or 75% (Karahadian and Lindsay, 1984).

The research sampled 4 formulations of cheese made with noniodized salt, 1.3% or 2.1% sodium chloride/potassium chloride, and nonsalted (Karahadian and Lindsay, 1984). Panelists were given samples as both cold slices of cheese and on open faced melted cheese sandwiches (Karahadian and Lindsay, 1984). There were 175-200 panelists in this trial.

Figure 7 shows that there were significant differences in the overall liking of full sodium and reduced sodium cheese formulations. The frequency distribution of the consumers showed that over 60% of participants rated the reduced sodium cheeses in the top three categories on a 7-point liking scale (Karahadian and Lindsay, 1984). This indicates even though there was significant difference between the different samples, the consumers overall did not dislike the samples with the reduced sodium chloride.

Several other investigators have evaluated various salt replacers, chiefly potassium chloride, in the production of low sodium cheddar cheese. Lindsay et al (1982) altered the total salt added and used a 1:1 NaCl:KCl mixture to lower sodium. Cheeses with a significant reduction in sodium were found to be not significantly different in bitterness, astringency, off-flavors, acid intensity, cheddar cheese flavor or firmness by a consumer panel. Salt intensity and overall preference was lower for the cheese made with 1.5% NaCl:KCl mixture. Kosikowski (1982) made reduced sodium cheese by supplementing the cheese milk with whole milk retentate (milk with water, ions, and other molecules less than 20 kDa reduced by ultrafiltration). The retentate increased protein, K, and Ca concentrations, cheese flavor, body/texture and slightly increased NaCl compared to unfortified reduced salt cheddar cheese; the overall salt reduction was 30-50 % relative to average commercial cheddar cheese. Reddy and Marth (1993) used a range of NaCl:KCl concentration mixtures to make Cheddar cheese with either 1.5 or 1.75% total salt, or unsalted cheese. The cheese had a preferential retention of K rather than Na when made with the different salts. Cheese made with any of the KCl formulations had similar pH, but lower pH than cheese made with

only KCl and higher pH than unsalted cheese. The KCl-containing cheeses had significant reduction in sodium content, but did show difference in chemical composition that could significantly alter sensory characteristics.

TABLE 5. Consumer preference panel evaluations of experimental full-sodium reference and reduced-sodium process cheeses as slices and melted cheese sandwiches.

Consumer preference ratings and scores	Full-sodium reference	Process cheese slices			Melted cheese sandwiches			
		% Response in upper three categories	Reduced-sodium version	% Response in upper three categories	Full-sodium reference	% Response in upper three categories	Reduced-sodium version	% Response in upper three categories
(Number of responses)								
Sessions for 55% reduced-sodium cheese								
Like very much (7)	56	79	41	75	26	76	19	68
Like moderately (6)	59		59		67		63	
Like slightly (5)	39		48		51		47	
Neither like nor dislike (4)	20		17		22		25	
Dislike slightly (3)	14		16		15		26	
Dislike moderately (2)	5		8		8		8	
Dislike very much (1)	2		6		1		2	
Mean scores ^x	5.51 ^a		5.23 ^b		5.21 ^a		4.96 ^b	
Sessions for 75% reduced-sodium cheese								
Like very much (7)	38	77	27	60	32	80	23	71
Like moderately (6)	65		53		60		53	
Like slightly (5)	49		37		38		39	
Neither like nor dislike (4)	19		25		16		13	
Dislike slightly (3)	15		29		9		22	
Dislike moderately (2)	6		21		4		7	
Dislike very much (1)	5		5		4		6	
Mean scores ^x	5.27 ^a		4.70 ^b		5.38 ^a		4.98 ^b	

^{a,b} Mean scores for samples with different superscripts within a panel session are significantly different ($P < .05$).

^x_n = 163 to 197 in each session.

Figure 7: Descriptive Sensory Properties of Cheeses (Karahadian and Lindsay, 1984).

Another technique industry has utilized to reduce sodium is to use flavor enhancers such as monosodium glutamate (MSG). MSG has been found to enhance salty flavor of products when used in combination with salt (Desmond, 2006). Industry also can apply a flavor enhancer to the partially substituted samples to enhance the perceived sodium with the reduced sodium chloride formulation of cheeses. The addition of “delta- gluconolactone”, which is a delayed acidulant, can alter the pH and give a sharp or stronger sour taste to foods (Karahadian and Lindsay, 1984). The addition of a small amount of delta-gluconolactone (0.1%) was found to have negative affects on the texture of the cheese and provided little to no enhancement of flavor (Karahadian and Lindsay, 1984).

In the US, 21% of sodium intake comes from meat and meat products (Desmond, 2006). The meat industry has found many difficulties with salt reduction in their products. Salt plays an important role in meat production for preservation and as a flavoring compound. It is also used to achieve texture properties in meats, by activating protein to increase hydration and water-binding capacity (Desmond, 2006; Gelabert et al., 2002). Meat industries not only have sodium reduction demands, but they are also faced with consumer demand for fat reduction. An increase in salt in a fatty product is perceived at lower concentration than in a lean product (Desmond, 2006). Therefore, a lower-fat meat product would need more salt to increase the perceived salty flavor.

Research has been conducted on the replacement of sodium chloride on fermented sausages. Potassium chloride, potassium-lactate and glycine were used as partial sodium chloride substitute (Gelabert et al., 2002). The study design consisted of sodium chloride

replacement by these three compounds up to 40%, by increments of 10% (Gelabert et al., 2002).

Physicochemical parameters and sensory characteristics of sausages from the control (C) and each of the KCl, K-lactate and glycine substitutions (10-40%) at the end of the process

	Control	KCl				K-lactate				Glycine				Rsd
		10%	20%	30%	40%	10%	20%	30%	40%	10%	20%	30%	40%	
pH	6.43	6.35	6.42	6.38	6.42	6.25	6.28	6.82*	7.03*	6.34	6.33	6.52	6.58	0.151
Moisture (%)	41.0	40.9	39.8	39.6	39.1*	39.7	39.9	41.0	41.8	39.6	42.3	42.1	41.0	0.99
TN (%)	5.77	5.36	5.52	5.41	5.83	5.51	5.51	5.37	5.31	5.56	5.88	6.32*	6.96*	0.313
NPN/TN	0.116	0.118	0.116	0.116	0.115	0.107	0.116	0.121	0.141	0.140	0.150*	0.149*	0.147*	0.0164
Cohesiveness ^a	4.4	4.6	3.6	4.0	4.0	5.2	4.8	3.0*	3.1*	5.0	3.3*	3.3*	3.0*	0.77
Hardness ^a	4.6	4.6	5.4	5.0	5.8*	4.7	4.5	3.9	3.7*	4.3	3.8	3.9	3.5*	0.69
Saltiness ^a	5.0	5.0	5.2	5.1	4.9	4.8	4.6	3.8*	3.9*	4.8	4.1*	3.9*	3.5*	0.48
Bitterness ^a	0.8	0.9	0.8	1.3	2.8*	–	–	–	–	–	–	–	–	0.83
K-lactate flavour ^a	0.5	–	–	–	–	0.5	1.2	2.6*	2.8*	–	–	–	–	0.96
Sweetness ^a	0.2	–	–	–	–	–	–	–	–	0.7	1.2*	1.8*	2.6*	0.59

Rsd: residual standard deviation. TN: total nitrogen. NPN: non-protein nitrogen.

^a Scores: 0 means absence of saltiness, bitterness, K-lactate flavour and sweetness or very low intensity of other parameters and 10 means very high intensity.

* Means significantly different with respect to the control ($P < 0.05$).

Figure 8: Sodium Chloride substitution and sensory characteristics (Gelabert, et al. 2002).

Figure 8 shows that the panelists found no significant difference in saltiness between the control and potassium chloride substitutions. Significantly less saltiness was detected with the potassium-lactate and glycine substitutions at or above the 30% and 20% concentrations, respectively.

These studies show the possibilities of a partial substitution of potassium chloride for sodium chloride in some products. There are nonprotein nitrogen (NPN) components found in whey permeates that may mask the bitter flavor that potassium chloride products produce (Harju, 2001). The masking ability of the whey permeates through NPN, could give an even greater reduction in sodium chloride in potentially high sodium chloride products.

Factors Affecting Salt Perception

Viscosity has been shown to affect salt perception in foods. It is commonly known that an increase in viscosity causes a decrease in salt perception (Izutsu and Wani, 1985; Malone, et al., 2003). Carboxymethylcellulose (CMC), short chain length CMC (CMC-L), xanthan gum, sodium alginate (SA), hydroxypropyl cellulose (HPC) were used to impart different rheological properties in a study by Pangborn et al., (1972). Salt perception was enhanced with increasing concentrations of CMC-L (Pangborn, et al., 1972) , but not affected by other thickeners. Saltiness was less affected by viscosity than other tastes. This study suggested that viscosity may not be an important factor in salt perception, but intensity of salt taste may depend on the type of thickener used.

Some speculation concerns other factors such as mouth-coating behaviors of thickeners, which may have a larger effect on taste intensity than viscosity alone (Malone, et al. 2003). Because fat tends to cause an increase in salty flavor, the reduction of fat could cause a decrease in salty taste. Malone, et al. (2003), found reduced fat cheeses to have a decreased saltiness which they attributed to a decrease in salt concentration in the aqueous phase. These researchers studied the effect of oil/water emulsions and found the increasing amount of oil in an emulsion with constant salt content gave a decrease in salt taste (Malone, et al., 2003). They suggested that salt intensity is based on salt concentration in the aqueous phase and aqueous phase volume (Malone, et al., 2003).

Rosett, et al., (1995) found there was an increase in salt perception when KCl was included in food. This study used ^{23}Na nuclear magnetic resonance (NMR) spectroscopy to

show that the sodium ion was attracted to the negatively charged ions and thus became bound in xanthan gum (Rosett, et al., 1995). This study showed that the ionic gums (xanthan and kappa carrageenan) were able to suppress the salt taste more than nonionic gums (lotus and guar). The xanthan gum decreased salt perception as compared to the locust bean gums even though the xanthan gum had a higher amount of Na^+ . With the addition of KCl to the ionic gums, Rosett, et al. (1995), found potassium ions competitively displaced sodium ions to give an increase in perceived saltiness.

In another study, Rosett, et al. (1997) measured the effect of temperature on saltiness in reduced sodium soups with and without thickeners. As in the previous study (Rosett et al., 1995), ionic and nonionic thickeners were used. The researchers again found no correlation between salt taste and viscosity (Rosett et al., 1997). However, salt intensity was more intense in the lower temperature soup (22°C) than in hotter soup (65°C) (Rosett et al., 1997).

Cold activation of amiloride-sensitive epithelial sodium channels (ENaC), the mechanism for salt taste reception (Sugita, 2006) may cause an increase in salt intensity in foods that are cold in temperature (Talavera et al., 2007). This mechanism supports the results found by Rosett et al., (1997).

Microbial Growth in Meat products

Since the main goal of the research is to reduce the sodium content of cream based soups, there is a concern with microbial growth in the product. With salt reduction and no use of another preservation method, the shelf life and preservation of meats are greatly reduced

(Desmond, 2006). There are also concerns with microbial growth with reduced sodium meat products. Data suggest that when salt is replaced by either potassium chloride or magnesium chloride, there are no significant differences in microbial growth (Desmond, 2006).

In a study conducted by Ibanez et al., (1997) sodium chloride was reduced in dry fermented sausages from 3% in control samples to 1.5% sodium chloride and 1% potassium chloride. Even though there was a higher water activity in the potassium chloride substituted product, there were no significant differences in microbial growth (Ibanez et al., 1997).

Prevention of growth of *Listeria monocytogenes*, *Clostridium*, *Staphylococcus aureus*, *Micrococcaceae*, Lactic acid bacteria, and aerobic mesophylic total count in sausages by salt substitutes was observed (Gelabert et al., 2002). In all measurements, except for *Micrococcaceae*, there were no significant differences in bacterial count between the control sausages and the potassium chloride containing sausages. *Micrococcaceae* was found to be slightly higher in potassium chloride treatment than the controls (Gelabert et al., 2002).

Commercially produced dry-cured hams are a traditional southern product and have high sodium content. It is mandated hams be treated for the destruction of *Trichinella spiralis*, have a weight reduction of 18.0% minimum, and contain 4% salt. Although some studies on salt substitutions in dry cured hams have shown that sodium reduction with 50/50 mixture of NaCl / KCl (Lite Salt™) had high levels of spoilage during commercial processing, increasing the Lite Salt™ application from 5.72% to 3.5% NaCl and 3.5% KCl (7% total salt) in the curing process prevented microbial spoilage (Pilkington and Allen, 1994). With both salt application levels, there were no viable trichinae in the hams

(Pilkington and Allen, 1994), thus suggesting there was enough salt absorption from the 50/50 mixture. An industry practice of stacking the hams during processing gave a greater absorption of salt. The total absorption of sodium was 30% less than the original curing process (Pilkington and Allen, 1994).

The sodium chloride in this research's cream soup is partially replaced by whey permeates, which contain a high amount of potassium chloride and other salts. The research suggests there should be no concern for microbial growth.

Definition of Whey Permeate

In defining whey permeate, there are many names that are associated with this potential waste product. Some names include, "dairy product solids," "mother liquor," and "De-proteinized whey" (Allen et al., 2002). Whey permeate is defined by the US Dairy Export Council as being "a source of dairy solids obtained by the removal of protein and some minerals and lactose from whey" (USDEC, 2004).

Production of Whey Permeate

Whey permeate is obtained as a by-product of cheese manufacturing. Whey is drained off of the curd and used to further remove whey protein and lactose. For every one pound of cheese produced, 9 pounds of liquid whey results (Parmentier, 2000).

Ultrafiltration is a process in which the whey, left over from cheese production, is passed

through a filter membrane that contains narrow pores (3 to 300 nm) (Walstra, 2006). The liquid that passes through the system is considered the permeate portion (USDEC, 2004).

When the whey passes through the membrane, macromolecules, like protein, are retained by the membrane. The smaller molecules, such as ions, pass through and are collected. As shown in figure 9, further processing of the permeate can be performed to remove lactose through crystallization.

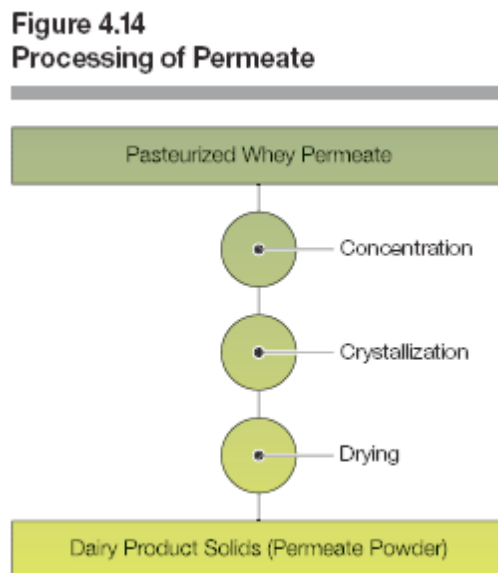


Figure 9: *Processing of Permeate (USDEC, 2004)*

The liquid that passes through the membrane filtration contains lactose and salts. With further processing, companies can collect lactose, which can be used in many food

applications, from the liquid. In most factories this remaining liquid is then stored in large barrels, and the product is disposed of as an ingredient in animal feed (Allen et al., 2002).

Land spreading is a common procedure for companies who cannot dispose of this “waste” into a Publicly-Owned Treatment Facility (POTW) (Frigo Cheese Corporation, 1996). The permeate is therefore, applied to nearby agricultural lands. This is becoming more difficult because regulations are becoming more strict on land spreading due to preservation of soil quality (Parmentier, 2000). One cheese manufacturer that produces about 2000 lbs of waste per day (Frigo Cheese Corporation, 1996) would spend approximately 5 cents per pound of waste (Parmentier, 2000). This calculates out to be about \$96 per day to dispose of waste or \$3000 per month. Discovering new uses for this “waste” product could potentially help reduce the cost of cheese manufacturing.

Characteristics of Whey Permeate

The general characteristics of whey permeate are a low protein content of 3.0-8.0%, due to the whey protein removal through ultrafiltration (Allen et al., 2002). Most permeates contain a high percent of lactose of 65-85% (USDEC, 2004). Some companies are able to extract this lactose and use it in bakery products to reduce sucrose use (USDEC, 2004).

Another characteristic of whey permeate is the high content of potassium when measured on a dry-matter basis (Allen et al., 2002).

Whey permeates are also a good source of calcium and magnesium. All of these minerals could be an added benefit to the diet. Americans commonly do not consume the recommended amount of calcium in the diet. Increased use of whey permeates could be a

potential source to increase calcium content in foods, which may help to reduce osteoporotic fractures. Magnesium may help regulate blood pressure as an inhibitor of vascular smooth muscle contraction (Mahan and Escott-Stump, 2004). There is little evidence of magnesium by itself being effective in reducing blood pressure, but there might be an effect when combined with the other minerals, potassium and calcium (Geleijnse et al., 1994).

Potassium is another great asset in whey permeates. The DRI for potassium is 4700 mg/d for adults, but intake of this cation has been found to be deficient in about 50% of Americans due to poor consumption of fruits and vegetables and dairy products (Mahan and Escott-Stump, 2004). The benefit of increased potassium intake among other dietary changes was effectively shown with the DASH diet with increased intake of fruits and vegetables and the decreased risk of hypertension. It was suggested that 1 or 2 more servings of fruits or vegetables per day could decrease hypertension by 40% (Mahan and Escott-Stump, 2004). A similar increase in potassium intake might be achieved through increased use of whey permeates in foods.

A randomized double blind placebo controlled trial was conducted on older adults between the ages of 55 and 75 years (Geleijnse et al., 1994). This trial aimed to show the benefit of increasing potassium and magnesium along with decreasing sodium intake. Overall, 97 participants provided usable data for analysis (Geleijnse et al., 1994). The control group was assigned sodium chloride for use in cooking (Geleijnse et al., 1994). The intervention group received a sodium/potassium/magnesium (41%/41%/17%) salt which was mined from Iceland (Geleijnse et al., 1994).

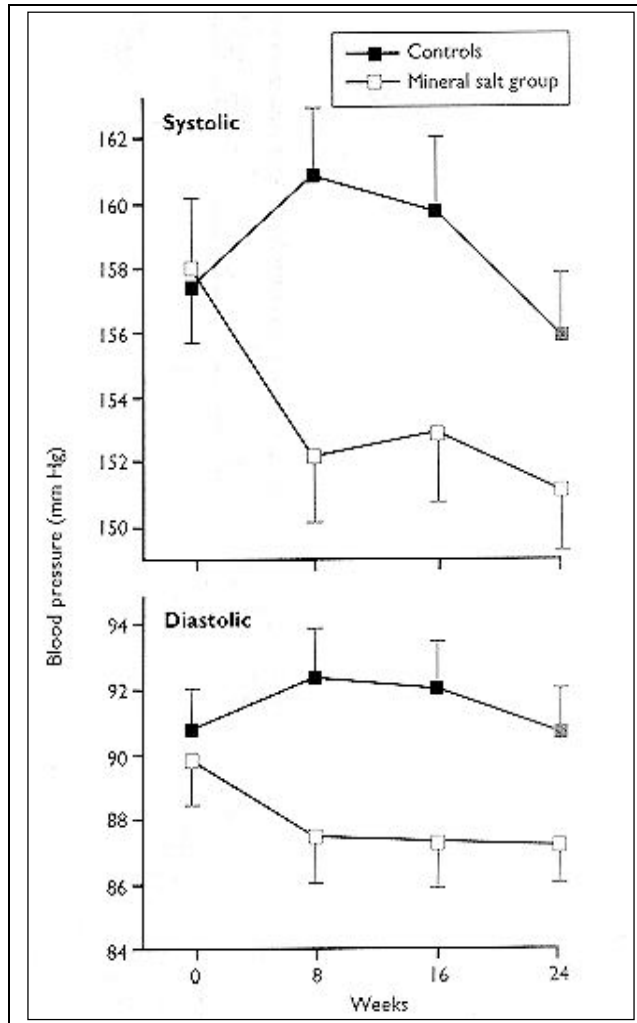


Figure 10: Mean systolic and diastolic blood pressures starting from baseline and through intervention (Geleijnse et al., 1994)

Figure 10 shows the significant drop in blood pressures occurring with the intervention group throughout the study. In this study, there was an average decrease in blood pressure of 7.6 mm Hg in diastolic pressures (Geleijnse et al., 1994). The overall

reduction of daily sodium was 38 mmol, with an increase in potassium and magnesium of 18 mmol and 7 mmol, respectively (Geleijnse et al., 1994).

The authors suggest some underlying causes that may have been responsible for such a dramatic decrease in blood pressure. Participants were older in age and as stated earlier, elderly persons are more affected by sodium changes in the diet (Geleijnse et al., 1994; Champagne, 2006; Smith et al., 2005; Nordin, et al., 2003). The full decrease of blood pressure seemed to be achieved around the eight week mark of the 24 week study (Geleijnse et al., 1994) as noted in figure 10. The researchers did note there were no detectable differences in blood pressure 25 weeks after the study concluded (Geleijnse et al., 1994).

Another statement by the researchers' supports the use of whey permeates as a potential benefit for health as a sodium substitute. The study suggested blood pressure may be affected more by mineral interactions than by one mineral alone (Geleijnse et al., 1994). Whey permeate, being high in potassium and magnesium, could possibly give these effects if used as a sodium substitute. Possible dose responses of varying levels of potassium, magnesium and sodium combinations could be further explored to support these ideals.

The major studies for hypertension, (DASH and TOPH), have both shown that there is an added benefit to reducing sodium intake in the diet (Champagne, 2006; Cook et al., 2007). Overall, a reduction of sodium in the typical American diet may reduce hypertension, especially in salt-sensitive people, elderly people, and African Americans. Whey permeates, a by-product of cheese manufacturing, could prove to effectively reduce the amount of total sodium within the diet, while still giving the satisfaction of a "full flavored" product. The

added benefits of potassium and magnesium further strengthen whey permeate as a good candidate for sodium substitution. With this new-found use for whey permeates, there is a potential for a reduction in food manufacturing cost for disposal of waste.

Research Objectives

The objectives of this research were: to select suppliers for whey permeate or delactosed permeate; evaluate salty flavor of products in comparison with known concentrations of sodium chloride to make comparisons of permeate and table salt through trained dairy flavor panels; gather mineral content of potential permeates to find potassium, magnesium, zinc, iron, and calcium levels; select soup formulations that meet research needs by being undesirably high in sodium and using dairy ingredients.

Two soup formulations were selected, one generic fresh soup and one using proprietary ingredients and formula, and compared by a consumer panel. With the use of selected whey permeate, flavorless cream soup formulations will be developed that optimize sodium reduction while retaining salty taste at a desirable level. Consumer testing judged acceptance towards the use of whey permeate in an unflavored cream soup. Mineral content analysis measured compliance with current labeling claims for “reduced sodium”, or “a good source” of potassium.

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Chapter 2

Manuscript to be submitted for publication

Whey Permeate, Delactosed Permeate, and Delactosed Whey as Ingredients to Lower Sodium Content of Cream Based Soups

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Abstract

The use of whey permeates as salt substitutes can help to decrease sodium and chloride intake, increase potassium, calcium and magnesium intakes and decrease hypertension risk. Five different whey permeates from 5 different manufacturers were analyzed with ICP for mineral content (Na, K, Ca, Mg, Fe, Zn). Two permeates are powder and three are liquid. Lactose and protein content were also analyzed by Lactose/D-Glucose UV kit from Roche and BCA protein assay, respectively. Chloride and phosphate were measured spectrophotometrically. Basic tastes and aromas were quantified by a trained sensory panel. Based on the highest “salty taste” identified by the trained sensory panel, one liquid and one solid permeate were further investigated as sodium substitutes. The sodium content of the guideline solutions for comparing salty taste of the permeates were used to calculate the equivalent concentrations of salt and permeate for salty taste in aqueous solution. Two soup formulations were used to test the use of permeate as a salt substitute; one retorted, canned, condensed cream soup base, and one fresh cream soup base. Each formulation of soup was tested on a separate day by 75 consumer panelists who averaged between 20 and 30 years of age. Four samples were given each day 0%, 50%, 100% of the standard salt content in condensed soup, and permeate at a content calculated to be equal in salty taste to the standard salt content. The permeate soup was ranked in salty taste slightly lower than the 50% sample for the fresh soup. In the retorted soups, the permeate was ranked slightly higher than the 50% sample. However, the fresh and retorted soup formulations made from permeate actually contained 11% and 19% as much sodium as the full-salt recipe, respectively. The

permeate soup was described as higher in salty taste than expected based on actual sodium content, but not as high as predicted from the salty taste of the permeate in aqueous solution. Potassium and magnesium levels were increased in the formulations with permeate. This research gives an optimistic view on the possibility of whey permeates and their capability of replacing sodium in cream soups and other processed foods.

Key Words: Whey Permeate; sodium substitution; reduced sodium; cream soup, potassium chloride

Introduction

Hypertension is one of the most prevalent chronic diseases in the U.S. Diagnosis of blood pressure higher than 140/90 mm Hg is considered hypertensive (USDA, 2005). There are many complications from hypertension, including cardiovascular disease and stroke. Although hypertension can be diagnosed, controlled or treated, about 32% of the participants in the third National Health and Nutrition Examination Survey were unaware they were affected by this disease (Mahan and Escott-Stump 2004).

Currently the Dietary Guidelines for Americans recommends that individuals consume less than 2300 mg of sodium per day and choose potassium-rich foods to lower blood pressure. The reduced salt intake by the population should follow from reducing the salt used in food processing (HHS/USDA, 2005). Currently the average consumption of sodium by Americans is about 3380 mg per day (Johnson and Kumanyika 2008). Staying under the dietary guidelines for sodium is difficult due to the large consumption of processed foods that contribute about 75% of the sodium in American diets (Antinoro, 2007). Compliance with low sodium diets is also difficult due to lower palatability of reduced sodium foods (Bosworth, 2008). About 60% of patients stop treatment after the first year of intervention (Bosworth, 2008). Culture, social surroundings, low palatability, and high consumption of processed foods are typical barriers faced when on a low sodium diet (Malherbe, 2003; Smith, et al. 2006). Due to the high intake of sodium from sources from which consumers are either aware or unaware, there is an increased need for salt substitutes that assist with reduced sodium intake.

One possible salt substitute could come from whey permeate. Whey permeate is also known as “dairy product solids,” “mother liquor,” and “deproteinized whey” (Allen, et al. 2008). Whey permeates are defined as, “a source of dairy solids obtained by the removal of protein and some minerals and lactose from whey” (USDEC 2004). Whey that is drained off during cheese making is ultrafiltered to remove whey proteins and the mineral salts and lactose flow through the membrane (Walstra, 2006). Within this by-product, there are many valuable minerals that could contribute to the dietary needs of the American population. Minerals like calcium, potassium and magnesium have been found to have an effect on hypertension. Potassium alone and in combination with calcium and magnesium may decrease blood pressure (Geleijnse, et al.1994). With substitution of whey permeate for part of the salt in processed foods, there is an opportunity for an increase of these vital minerals with a decrease in dietary sodium and possibly hypertension.

Materials and Methods

Materials

Due to the many terms for permeate, a representative from the sponsoring organization (Dairy Management Incorporated, DMI) made arrangements for companies to send whey permeate from cheese manufacturing that had low protein and high mineral salt content. Permeates were sent from 6 different companies. Preliminary data were collected

on these permeates to select the permeate with the optimal flavor and mineral content. Ingredients for retorted condensed soup were provided by a commercial soup company.

Methods

Pasteurization of Permeates

Upon arrival, each liquid permeate was pasteurized to ensure the product was safe for human consumption. A food grade water bath was heated to 75 °C. Samples were submerged up to the top of each bottle until the internal temperature of the permeate was brought to 63 °C and held at this temperature for 30 min. Each sample was removed from the hot water bath and quickly placed into the freezer, where it was held until further use.

Mineral Analysis

Mineral analysis was performed by the Soil Science Department at North Carolina State University. For each permeate, analyses were conducted to find calcium, potassium, magnesium, sodium, iron and zinc concentrations by inductively coupled plasma spectrophotometry (ICP).

Lactose Analysis

Each sample was analyzed for lactose concentration with *R-Biopharm* Lactose/D-Glucose kit. For every permeate, 5 dilutions were created in a 1:10 series in order to catch the optimal concentration and range for the kit.

For the lactose measurement, citrate buffer (0.2 mL) and β -Galactosidase suspension (0.050 mL) was added to each cuvette. The different permeate dilutions (0.100 mL) were added to each cuvette leaving one empty as a blank. The cuvettes were vortexed and set aside to incubate for 20 min at 20-25 °C. TRA buffer/NADP/ATP (1.0 mL) was then added to each cuvette along with 2.0 mL of redistilled water. Each cuvette was then mixed and set aside for 2 minutes. HK/G6P-DH suspension (0.020 mL) was then added to each cuvette and set aside for 15 min. Absorbance at 340 nm was measured from each cuvette and recorded at intervals of 2 minutes until the reaction stopped. Concentration was calculated with the formula provided by the kit,

For lactose:

Equation 1

$$c = \frac{V \times MW}{\epsilon \times d \times v \times 1000} \times \Delta A \text{ [g/l]}$$

V = final volume [ml]
 v = sample volume [ml]
 MW = molecular weight of the substance to be assayed [g/mol]
 d = light path [cm]
 ϵ = extinction coefficient of NADPH at
 340 nm = 6.3 [l × mmol⁻¹ × cm⁻¹]
 Hg 365 nm = 3.5 [l × mmol⁻¹ × cm⁻¹]
 Hg 334 nm = 6.18 [l × mmol⁻¹ × cm⁻¹]

It follows for lactose (calculated as anhydrous lactose):

$$c = \frac{3.270 \times 342.3}{\epsilon \times 1.00 \times 0.100 \times 1000} \times \Delta A = \frac{11.19}{\epsilon} \times \Delta A_{\text{lactose}} \text{ [g lactose/l sample solution]}$$

Obtained from r-Biopharm)

For glucose:

Equation 2

$$c = \frac{3.270 \times 180.16}{\epsilon \times 1.00 \times 0.100 \times 1000} \times \Delta A_{\text{D-glucose}} = \frac{5.891}{\epsilon} \times \Delta A_{\text{D-glucose}}$$

[g D-glucose/l sample solution]

(Obtained from r-Biopharm)

Protein Analysis

A Pierce® BCA (bicinchoninic acid) assay was performed to determine the protein content of each permeate. The dilution scheme for the test tube protocol was used to analyze the samples.

Table 1: Modified Dilution Scheme for BCA Test Tube Protocol (Thermo Scientific 2008)

Standard	Water	Standard	Protein (mg/mL)
A	100 uL	0 uL	0.00
B	75 uL	25 uL	0.50
C	50 uL	50 uL	1.00
D	25 uL	75 uL	1.50
E	0 uL	100 uL	2.00

A working reagent was prepared for the test tubes based on the total volume of the permeates to be analyzed. Each of the standards and unknowns were placed into their respective test tubes. Two milliliters of the working reagent was pipetted into each test tube and mixed with a vortex mixer (Thermo Scientific 2008).

Absorbencies of all test tubes were measured within 10 minutes using a spectrophotometer set at 562 nm. Absorbance of the blank test tube, was subtracted from the absorbance reading of each unknown test tube (Thermo Scientific 2008). The resulting value was compared to the standard curve to determine the unknown protein concentrations of the permeates.

Raw Permeate Descriptive Panel

In order to determine the best permeate to test in condensed soups, a panel of 10 to 12 people trained in dairy flavors sampled each permeate. A preliminary tasting of the six permeates in a 10% solution (90% deionized water and 10% permeate) was conducted in order to determine flavors and aromas of all permeates. Descriptors of cardboard, canned meat, fruity, nutty, vitamin were found in the permeates, and sweet, sour, salty, umami, and

brothy were asked to be rated in intensity. Aroma was also given with descriptors of canned meat, fruity, nutty, vitamin, sour, and brothy. Five different panels were held to profile each permeate with the varying flavors and aromas. Each product was tested on 2 different days.

At each panel, each panelist was given distilled water and an empty cup for expectoration. All references were made with deionized water. References for salt (NaCl) were valued at 5 and 8. These values equaled 0.7% and 0.9% solutions, with 7 grams and 9 grams per liter, respectively (Meligaard, 1991). Sour and bitter references were also given which were made from citric acid and caffeine, respectively. For both tastes, values of 2 and 5 were given which were 0.05% and 0.08% solutions (Meligaard, 1991). This calculates to be 0.5 and 0.8 grams per liter for values 2 and 5. Umami reference values were 3 and 6. Percent solution for each value was 0.5% and 1.0%, being 5 grams and 10 grams per liter, respectively (Meligaard, 1991). The final reference given to the panel was a sweet reference with values of 2 and 5. The percent solution for these values was 2 and 5, with 20 grams and 50 grams of sucrose per liter, respectively (Meligaard, 1991). All permeates were rated for flavor and aroma intensities as described with the trained dairy flavors panel. The flavor and aroma intensities were analyzed by 2-way analysis of variance using permeate product supplier and day of analysis as main effects and product x day interaction in the model. Significant differences between products were computed using Tukey's HSD test with JMP software (SAS, Inc., Cary NC).

Selection of Permeate

After the sensory panel of the raw permeate and the analysis of the mineral content of the permeates, one permeate was selected. Company E permeate was chosen for additional study based on mineral composition, flavor profile, and its powdered consistency. The salt added to a full salt recipe (denoted as 100% salt) within each soup recipe was set at 3.15 grams of salt per cup (237 mL) of soup. This amount of salt was used for both the retorted and fresh soup recipes. In order to compare the saltiness of the soups containing salt and permeate as a salt substitute, formulations with less than 100% salt, 0% and 50% salt, were also prepared for each recipe.

Cream Soup Recipe

A proprietary soup recipe, which was a retorted unflavored cream based soup, was obtained as a basis for comparison with a fresh, public domain cream based soup recipe. The fresh soup ingredients included in the recipe are as follows, (Walstra, 2006):

<i>Table 2: Ingredients for Fresh Cream Soup, obtained from http://www.thatsmyhome.com/soupkitchen/cream-of-anything-soup.htm</i>	
Amount	Ingredient
2.5 cups	Whole milk
½ cup	Flour (all-purpose)
2 tablespoons	Butter (unsalted)
Dash	Salt

This recipe was modified by trial and error to develop an unflavored cream soup.

During preliminary preparation of the fresh soup and informal tasting by an untrained panel, the original recipe was modified to reduce viscosity and allow saltiness comparisons.

Table 3: Revised Recipe for fresh soup	
Amount	Ingredient
2.5 cups	Whole milk
¼ cup	Flour (all-purpose)
2 tablespoons	Butter (unsalted)
As formulated	Salt

The flour was reduced to ¼ cup in order to reduce thickening of the soup. Whole milk and unsalted butter were also used in the ingredients, for creaminess and to avoid unmeasured additional salt, respectively. No salt or pepper was added to the soup, to reduce additional salt and add no other flavors. No flavors were added to the cream soups in order to analyze the salty taste of the sample soups without any flavor interactions.

To prepare the fresh soup, the instructions that accompanied the fresh soup found on the Internet were followed. A roux was created by melting butter in a large sauce pan. The flour was slowly added to the butter while whisking the two together to create a smooth consistency and to coat the flour. The milk was then whisked into the mixture. The permeate or salt, was then added to the mixture. The soup was allowed to come to a boil, with constant stirring. Once the soup started to boil, the heat was turned down and the soup was served to the panelists. This recipe makes about 3 cups (726 mL) of soup.

Preliminary Soup Trials

A small untrained panel consisting of laboratory colleagues was used to do preliminary tasting on the condensed soups to find the appropriate saltiness for consumer trials and also to reduce waste with the retorted canned version. The trained sensory panel found equivalent salty taste for 13.3 g Company E permeate powder and 1 g NaCl in solution. Therefore, the calculation for the amount of Company E permeate to add to the soup was found:

Equation 3

$$3.15 \text{ g NaCl per cup of soup} * 13.33 \text{ g Company E permeate powder per g of NaCl} = 41.895 \\ \text{grams permeate per cup of cream soup}$$

Each panelist was given samples with varying concentrations of salt; 0%, 50%, 100% of the NaCl called for in the recipe, and also Company E's permeate with equal salt taste concentration of 100% salt. Each panelist rated their liking of each sample on a 9-point hedonic scale, 0 being not salty, and 9 as too salty. A just about right scale (JAR) was also used to determine each panelist's opinion of the perceived concentration of saltiness. The panelists were also asked to rank each sample from lowest to highest saltiness perception.

Retorted Canned Soup

The proprietary soup recipe was retorted using a Model PR-900 Pilot Retort. The canned version of cream soup was prepared according to the instructions supplied. All cans were sterilized, hot filled and sealed with an automatic can seamer, then placed into the retort. The cans used for the canning process were number 1 cans also known as picnic cans (211 x 400). The retort was allowed to run according to the full water immersion procedure in table 4.

The retort process was completed in approximately one hour. After sufficient cooling, all cans were removed and stored for two weeks to observe for leaks and bulges.

<i>Table 4: Operation Temperatures and Times for Retort, Recipe #00, Full Immersion Test Recipe (obtained from Model PR-900 Pilot Retort)</i>					
Step	Temp. (°F)	Pressure (psi)	Time	Temp. Gradient	Press. Gradient
Heating	220	20	-	-	-
Storage Vessel					
Sterilization I (Vent)	180	20	20 sec.	-	-
Sterilization II (Come-up)	242	30	8 min.	10	-
Sterilization III (Hold)	242	30	35 min.	-	-
Cooling 1	-	20	20 sec.	-	-
Cooling 2	90	10	20 min.	-	0.6
Drain	90	-	4 min.	-	-

Consumer Panel

Two consumer panels were conducted with 75 people for Company E's permeate in the retorted condensed soup and in the fresh soup recipes and three other sample soups that contained 100%, 50% and 0% salt. A soup version (fresh or retorted) was served on one day with a total of 4 soup samples per day.

The fresh soup was prepared as described previously. The canned retorted soup was prepared by adding one can of soup with one can of water and heating to a simmer. When each soup reached a simmer, they were placed in four-ounce squat Styrofoam cups. All extra samples were held at 65 °C in a warming oven to prevent bacterial growth (Rosett, 1997). Approximately one ounce of soup was given to each panelist. All panelists were given deionized water to rinse after each sample and an expectoration cup. Samples were randomized and had a forced rest of one and a half minutes between samples to reduce the likelihood of adaptation to salty taste.

Paper ballots were used, asking overall liking, overall flavor intensity, and salty taste intensity on a 9-point hedonic scale, with a score of 0 as strongly dislike and a score of 9 as strongly like. A Just About Right (JAR) scale was also used to assess salty level in each sample. After consumption of each sample, panelists were asked to rank each sample according to salty taste intensity from low to high. Demographic questions were also asked, such as age and sex. Whether the consumer was the household's primary shopper and what

influences their decision for purchases, such as price, nutrition, and brand were also asked. Soup intake and soup brand preferences were asked to assess frequency and brand choices pertaining to soup. Purchases of 25% reduced sodium soups was also asked to evaluate purchase frequency and also opinion on 25% reduced sodium soups.

Mineral Analysis of Cream Soups

Upon completion of each panel, the sample soups were collected and prepared for mineral analysis by the Analytical Services Laboratory in the Soil Science Department of North Carolina State University. Each permeate was dried until moisture content was reduced as low as possible. The dried soup was then weighed and ground into particles less than 2 mm in diameter. The samples were placed into sterile sample bags and delivered to the Analytical Services Laboratory. Mineral content was analyzed by ICP.

Results

Preliminary Data

Table 5 shows analytical data for all potential permeates to be used within the creamed soups. The data for the liquid permeates in Table 5 were converted to a dry matter basis in based on the measured moisture content. Company B permeate was dropped after some initial testing due to insufficient supply. The liquid permeates from supplier Companies A, C, and D had an average dry matter of 35%. Both powdered permeates, E and

F, had a dry matter of 98%. All permeates had an average ashed weight of 62% of dry matter. The sum of the cations measured was 43% of dry matter.

The liquid permeates had an average lactose contents with 283 g/kg of lactose. The powdered permeates contained similar lactose content averaging 85 g/kg. This means the permeate that we acquired was not processed through a lactose crystallization process.

Protein analysis showed that there were varying amounts of protein among the different permeates. Of the liquid permeates, Company B had the lowest protein content of 6.68 g/kg DM. In contrast, Company D had 12.38 g/kg of protein within their permeate.

Mineral analysis results showed that Company D liquid permeate contained the highest sodium of 12174 mg/L. Company E powdered permeate contained the highest sodium content of 11428 mg/kg. Potassium, magnesium and calcium were also the highest in Company D and E.

During the raw permeate panel, key descriptors of the permeates were noted and each permeate was rated against these descriptors (Table 6). Company C permeate was the only product where canned meat flavor was detected and, Company D permeate was noted for fruity, nutty and sour aroma, but this descriptor was not detectable in any other permeate products. Descriptor of vitamin aroma was only detected in company A and D permeates, which were both significantly different from one another. Most permeates portrayed the characteristic of brothy or chicken aroma, except for company D permeate. Permeates A and C were significantly different from E and F. Flavor was described in most permeates for cardboard, brothy/chicken, sweet, salt, and umami. Canned meat, fruit, nutty, vitamin, and

bitter flavors were not detected in most permeates for flavor. Values for these flavors are shown in table 6. After comparing all permeates and their rated descriptors, Company E was chosen to be used in the cream soup due to its numerically higher salty flavor and its powdered state.

Day of sampling was not a significant main effect for any of the flavors or aromas. The interaction of product and day of sampling was significant for sour aroma, nutty favor, and sweet taste, meaning that the products indicated were not scored the same on both sampling days.

<i>Table 5: Analyses of whey permeates expressed on a dry matter basis.</i>										
	Ash %	Na (g/Kg)	K (g/Kg)	Mg (g/Kg)	Ca (g/Kg)	Fe (mg/Kg)	Zn (mg/Kg)	Glucose (g/kg)	Lactose (g/kg)	Protein (g/kg)
	Liquid Products									
Company A	30.1	8.6	31.1	1.04	2.10	0.078	0.337	3.52	198.5	7.04
Company B	65.5	23.0	83.0	2.07	3.70	0.121	0.655	3.71	N.A.	6.68
Company C	66.1	30.4	47.1	2.15	4.78	2.003	1.706	0.91	251.5	10.30
Company D	85.7	39.7	87.9	2.62	5.71	0.544	0.873	5.21	397.4	12.38
	Dried Powder Products									
	Ash %	Na (g/Kg)	K (%)	Mg (%)	Ca (%)	Fe (mg/Kg)	Zn (mg/Kg)	Glucose (g/kg)	Lactose (g/kg)	Protein (g/kg)
Company E	10.4	11.4	3.13	0.181	0.78	0.55	1.73	0.14	88	10.4
Company F	9.47	10.6	2.61	0.150	0.71	6.72	5.28	1.02	81	9.47
N.A. = not analyzed										

Table 6: Descriptive Panel Sensory Evaluation. Scores are means of 10 to 12 panelists on 2 replicate days.

	<u>Company A</u>	<u>Company C</u>	<u>Company D</u>	<u>Company E</u>	<u>Company F</u>
<i>Aroma</i>					
Canned Meat	ND	2.35	ND	ND	ND
Fruity	ND	ND	2.10 ^a	ND	ND
Nutty	ND	ND	1.34 ^a	ND	ND
Vitamin	0.750 ^a	ND	1.43 ^b	ND	ND
Sour aromatic	ND	ND	0.868 ^{a*}	ND	ND
Brothy (Chicken or Potato)	1.87 ^a	2.01 ^a	ND	1.42 ^b	1.59 ^b
<i>Flavor</i>					
Cardboard	1.81 ^a	0.945 ^a	ND	1.09 ^a	0.818 ^a
Canned Meat	ND	2.25	ND	ND	ND
Fruity	ND	ND	1.76	ND	ND
Nutty	ND	ND	1.44 ^a	ND	0.708 ^{b*}
Vitamin	ND	ND	1.68	ND	ND
Brothy (Chicken or Potato)	1.40 ^c	1.87 ^{ab}	1.45 ^{bc}	1.67 ^{abc}	1.88 ^a
Sweet taste	1.31 ^{bc}	1.18 ^{c*}	1.64 ^b	2.80 ^{a*}	3.12 ^a
Sour taste	1.05 ^b	1.71 ^a	1.98 ^a	1.26 ^b	1.07 ^b
Salty taste	1.23 ^d	1.62 ^c	3.80 ^a	2.17 ^b	2.06 ^b
Umami taste	1.43 ^b	1.76 ^b	2.50 ^a	1.70 ^b	1.50 ^b
Bitter Taste	ND	1.04	ND	ND	ND

^{a,b,c} Values within a row sharing a superscript letter are not significantly different from each other (Tukey HSD of main effect) ($P < 0.05$).

*Significant product x day interaction ($P < 0.05$); product was not scored the same on the 2 days.

ND = not detectable for all means less than 0.5

Retort Internal Thermal Temperatures

Time and temperature measurements were recorded during the processing of the retorted canned version of cream soup.

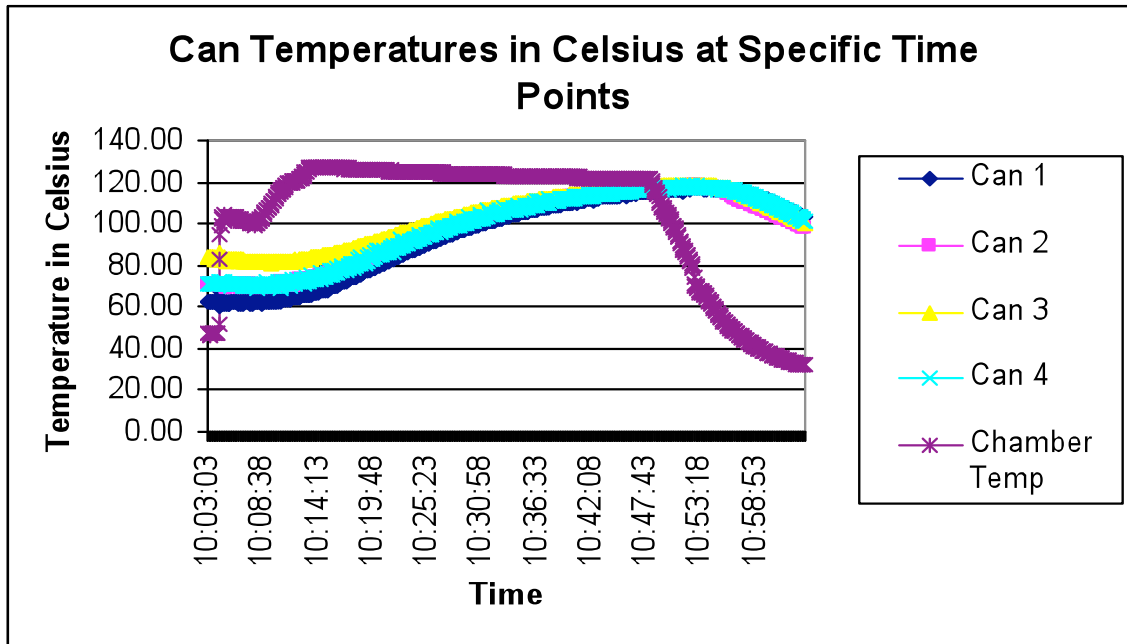


Figure 11: Can Temperatures in Celsius at Specific Time Points

Five cans were specially fitted with thermocouples to take internal temperatures of the cream soup during the retort process. Figure 1 confirms that heat transfer throughout the retort chamber elevated temperatures for all cans and also confirms the cans reached sufficient temperatures for destruction of bacteria.

Consumer Panel Data

The first consumer panel consisted of 22 men, 48 women, and 5 participants who did not record gender. The ages of most participants were between 20 and 30 years old. On average the participants consumed cream-based soups at least once a month. More men than women purchased reduced-sodium soup on average, and men rated themselves more knowledgeable about sodium and health effects than did women. Women did rate themselves as the primary shopper more often than did men. Nearly all who participated in the first consumer panel selected nutrition as being a major influence on their purchases.

On the first day of consumer panels, the fresh soup formulation was sampled. Overall liking, overall flavor intensity, salty taste intensity were all scored based on 9-point hedonic scales. The fresh soup consumer panel results in Table 7 show there was no significant difference in overall liking between the permeate-containing and 0% salt soups. The 50% salt soup was the best-liked sample overall. Similar results occurred for the intensity of the flavor of soups. The permeate and 100% salt-containing soups had the highest flavor intensity with no significant difference between them. The 100% salt sample had the highest salty taste intensity at 7.73 on the 9 point hedonic scale. Permeate- and 50% salt-containing soups scored on average 4.6 on the 9-point hedonic scale. The JAR scale scored 0% salt as the lowest and 100% salt as too salty. Permeate- and 50% salt-containing soups were in between “not salty enough” and “just about right”, and not significantly different from each other.

Table 7: Fresh Soup Consumer Panel Ballot Results

	<u>0% Salt</u>	<u>50% Salt</u>	<u>100% Salt</u>	<u>Permeate</u>
Overall Liking¹				
Average	2.72 ^b	5.00 ^a	3.89 ^a	3.31 ^b
SEM	0.17	0.23	0.26	0.25
Overall Flavor Intensity¹				
Average	2.45 ^c	4.63 ^b	5.93 ^a	5.73 ^{ab}
SEM	0.18	0.23	0.25	0.26
Salty Taste Intensity¹				
Average	2.00 ^c	4.97 ^b	7.73 ^a	4.31 ^b
SEM	0.18	0.20	0.17	0.25
JAR Scale²				
Average	1.55 ^c	2.88 ^b	4.07 ^a	2.69 ^b
SEM	0.10	0.08	0.09	0.12
^{a,b,c} Values within a row sharing a superscript letter are not significantly different from each other ($P<0.05$). ¹ 9-point hedonic scale ² JAR scale key: 1 = Not Nearly Salty Enough; 2 = Not Salty Enough; 3 = Just About Right; 4 = Too Salty; 5 = Much Too Salty				

Table 8: Fresh Soup Salty Perception Ranking.

<i>Ranking</i>	1 (Low)		2		3		4 (High)		Mean Ranking ± std dev
	<i>Frequency</i>	<i>%</i>	<i>Frequency</i>	<i>%</i>	<i>Frequency</i>	<i>%</i>	<i>Frequency</i>	<i>%</i>	
0% Salt Soup	58	81.7	5	7.0	5	7.0	3	4.2	1.33 ± 0.72 ^d
Permeate Soup	8	11.3	41	57.7	18	25.4	4	5.6	2.25 ± 0.61 ^c
50% Salt Soup	2	2.8	24	33.8	41	57.7	4	5.6	2.66 ± 0.76 ^b
100% Salt Soup	3	4.2	1	1.4	7	9.9	60	84.5	3.75 ± 0.74 ^a

^{a,b,c} Values within a column sharing a superscript letter are not significantly different from each other ($P < 0.05$).

Table 8 shows most panelists were able to correctly identify the lowest sodium content sample with the 0% salt taste sample. The 100% salt sample was identified as the highest salt taste content by the majority of the panelists in this panel. In this panel, the ranking score shows more people marked permeate-containing as lower in salty taste than the 50% salt formulation for the fresh soup.

The second consumer panel tested the retorted condensed soup. The consumer panel consisted of 24 men, 45 women, and 6 participants who did not answer the gender question on their score sheet. Most of the participants were between the ages of 20 and 30 years. More women marked themselves as the primary shopper than did men. The panelists considered themselves somewhat knowledgeable about sodium nutrition and its effects on health. The panelists marked their consumption of cream soup as between “at least once a month” and “once a year”. Also 25% reduced-sodium soup was more frequently purchased by women than by men. Nutrition was also a main concern when purchasing cream soups, but only 17 participants in the study marked sodium content of the food to be a main concern in purchasing. This suggests that even though people are thinking about nutrition during their cream soup purchases, they are not necessarily concerned with the sodium content of the soup.

For the second consumer panel, the 100% salt formulation was the most liked overall, and the 0% salt was the least liked (Table 9). The 0% salt formulation was scored to have the least amount of flavor intensity and 100% salt and permeate-containing soup had the highest intensity. The panelists were once again able to identify 0% salt as the least salty and 100%

salt as the highest salty taste intensity. The permeate soup was ranked by this panel with a numerically higher salty taste than the 50% salt-soup, although the two were not significantly different. The 100% salt sample was rated as just about right, whereas both 50% and the permeate soup scored as being not salty enough.

Table 9: Retorted Condensed Soup Consumer Panel

	0% Salt	50% Salt	100% Salt	Permeate
Overall Liking¹				
Average	1.72 ^c	2.85 ^{ab}	3.76 ^a	2.32 ^{bc}
SEM	0.14	0.19	0.23	0.18
Overall Flavor Intensity¹				
Average	1.71 ^c	2.97 ^b	4.64 ^a	4.31 ^a
SEM	0.16	0.21	0.24	0.29
Salty Taste Intensity¹				
Average	1.27 ^c	3.01 ^b	5.49 ^a	3.28 ^b
SEM	0.09	0.19	0.25	0.23
JAR Scale²				
Average	1.15 ^c	2.03 ^b	3.21 ^a	2.15 ^b
SEM	0.05	0.10	0.12	0.10
^{a,b,c} Values within a row sharing a superscript letter are not significantly different from each other ($P<0.05$). ¹ 9-point hedonic scale ² JAR scale key: 1 = Not Nearly Salty Enough; 2 = Not Salty Enough; 3 = Just About Right; 4 = Too Salty; 5 = Much Too Salty				

A higher percentage of the panelists ranked saltiness with the permeate-containing sample of the retorted condensed soup numerically higher than the 50% salt sample (Table 10). Once again, 0% and 100% salt samples were accurately ranked as being lowest and

highest, respectively, but their rankings were not able to significantly differentiate between the permeate-containing and the 50% salt-containing soups (Table 10).

Table 10: Retorted Condensed Soup Salty Perception Ranking

(Lowest)	Rank = 1		Rank =2		Rank =3		Rank =4(Highest)		Mean ± std dev	
<i>Bin</i>	<i>Frequency</i>	<i>%</i>	<i>Frequency</i>	<i>%</i>	<i>Frequency</i>	<i>%</i>	<i>Frequency</i>	<i>%</i>	Ranking	<i>%</i>
No Salt	68	91.9%	4	5.4%	0	0.0%	2	2.7%	1.14 ^c	0.57
50% Salt	3	4.1%	36	48.6%	30	40.5%	5	6.8%	2.50 ^b	0.80
Permeate	1	1.4%	24	32.4%	35	47.3%	12	16.2%	2.81 ^b	0.67
100% Salt	2	2.7%	10	13.5%	9	12.2%	55	74.3%	3.54 ^a	0.74

^{a,b,c} Values within a column sharing a superscript letter are not significantly different from each other ($P<0.05$).

Mineral Analysis of Cream Soups

The permeate-containing formulations had 11% and 19% as much sodium as the 100% salt soups for the two different versions of cream soups. All samples of the soups, for both panels contained a Na concentration very close to the formulated concentration. Based on the dry matter calculated for the 0, 50%, 100%, and permeate versions of the fresh soup (19.3, 20.1, 21.0, and 31.2% dry matter, respectively), the sodium content was 0.285, 4.10, 8.16, and 2.67 g/L, or 67, 970, 1930, and 630 mg per cup fresh soup, respectively. The permeate versions of both soups had significantly more magnesium and potassium in the cream soups than did the formulations with salt (Table 11). Zinc was the lowest in the permeate soups and iron was approximately equal in all soups. Chloride content was proportional to the amount of salt added to each soup, as expected. There was not enough sample for one soup for analysis of chloride concentration. Calcium content was much higher in the soups that contained permeate. Nearly twice as much permeate was added to the condensed soups as the fresh soup on a dry matter basis because of the condensed soup was designed to be served after a 1:1 dilution with water.

Table 11: Mineral Content of Cream Soups (Dry-matter basis)							
Fresh Soup							
Fresh Soup	Mg_Conc %	K_Conc %	Fe_Conc mg/kg	Zn_Conc mg/kg	Na_Conc g/kg	Ca_Conc g/kg	Cl %
100% Salt	0.051	0.73	27.7	18.7	29.24	53.14	4.90
50% Salt	0.054	0.72	17.0	22.6	15.56	56.41	2.94
0% Salt	0.044	0.57	20.1	17.1	1.54	41.44	0.43
Permeate	0.101	1.45	16.2	8.8	4.65	62.42	1.15
Retorted Soup							
	Mg_Conc %	K_Conc %	Fe_Conc mg/kg	Zn_Conc mg/kg	Na_Conc g/kg	Ca_Conc g/kg	Cl %
0% Salt	0.019	0.18	27.0	4.6	1.48	0.544	0.13
50% Salt	0.017	0.22	15.8	10.2	20.40	0.519	3.08
100% Salt	0.017	0.22	28.3	17.8	38.96	0.547	*NSS
Permeate	0.126	2.37	26.3	5.9	8.55	64.60	1.66
*Not Sufficient Sample							

Discussion and Conclusions

Upon comparison of the permeates, Company E was chosen for the permeate to be used as the salt substitution in both the fresh soup recipe and the proprietary retorted condensed soup recipe. Two different cream soups were used due to the confidentiality of the proprietary formulation. This is due to the industry's preference for a powdered salt substitute and the overall flavor characteristics of Company E's product determined by the trained panel and the mineral analysis. The Company F powdered permeate was very similar to the Company E product. Soup made with Company F permeate would probably give very similar results to those in this study. The soups were both unflavored, bland, cream-based soups. These versions of soups were created to find acceptability of the permeate used in the soups.

Comparing the demographics of both panels, we see panelists were similar in age and gender percentages on both days. People who participated in both panels were given a small gift card, so there was substantial overlap among the participants of the two panels. The women on both days marked themselves as the primary shopper and almost all participants indicated that they consider nutrition as a major factor in purchasing soup. Comparing these answers with the answers marked for the people who purchase 25% reduced soups, we observed that sodium content is not a primary concern while purchasing cream soups.

The data showed that 27% and 21% of the men and 23% and 35% of women in the two panels marked sodium as a concern for purchasing cream soup. Within the comments

section of the demographic questions, participants were asked why they did not purchase 25% reduced-sodium soups. Many of the participants stated their reason was due to the lack of flavor or poor flavor of the cream soup. This research confirms the findings of Malherbe, et al (2003), who stated that low sodium soups tended to be bland, tasteless and boring in flavor. For a person who suffers from hypertension, the findings of this research may help a person overcome the barrier of diet compliance due to lack of reduced sodium food choices or overall dislike of reduced-sodium flavor options (Karanja, 2007; Malherbe, 2003).

In the fresh soup consumer acceptance trials, the permeate soup had the same overall liking score as the 0% salt sample on the 9-point hedonic scale. Overall flavor intensity was found to be not significant between the permeate soup sample and the 100% salt soup or the 50% salt sample. Salt intensity was not significantly different between the permeate and 50% soup samples. Using the JAR scale, the consumers also found no significant difference between the permeate and 50% salt samples. They were both rated to be “not salty” enough. When the consumers were asked to rank the salty taste of each soup sample, the permeate was found to be lower in rank than the 50% salt soup.

In consumer acceptance trials with the retorted canned soup samples, overall liking was lower for the permeate soup than the 100% salt soup samples. The permeate soup was not different from either the 0% or 50% salt soups in overall liking. Overall flavor intensity was not significantly different between the 100% salt sample and the permeate sample. The flavor the consumers are finding and rating in this answer does not necessarily mean saltiness. The flavor differences between the permeate and 50% salt may be due to other

flavors found in the permeate, such as, canned meat, which the trained panel described in earlier raw permeate descriptive panels. The permeate and 50% salt soup sample were found to have no significant differences in salty flavor. This means consumers were not able to tell the difference between the 50% salt sample and the permeate version. The permeate sample did rank higher numerically, but not statistically, in the Just About Right scale than the 50% salt sample, and was significantly lower than the 100% salt version. Statistically the consumers rated the permeate soup to be closer to “just about right” (value = 3) than the 50% salt sample, but not as close as the 100% salt soup. When the consumers were forced to rank the salty taste, there was no significant difference between the 50% salt sample and the permeate sample.

This discrepancy between the ranking and JAR scales may be due to the difference in the consistency between the two versions of soup. The fresh soup had a thicker consistency and would become almost gel-like if left at room temperature for more than 20 minutes. The retorted soup was thinner and had an oily layer when served. Interactions between the varying ingredients within the two different soups could be the reason for the difference in salty taste intensity. This was demonstrated by Adam and Maller (1995), who found the complexity of food, does interact with the perception of salt flavor. The fat content of both soups were different in amount and in type. The fresh soup contained two tablespoons of butter per three cups of cream soup. Due to proprietary reasons, the fat content of the retorted soup cannot be disclosed. The difference between fat content and type of fat used within each cream soup may be why there were different perceptions of salty content.

Mineral analysis of the soups used during the consumer panels showed it is possible to reduce actual sodium content and have a higher salt taste due to the mineral salts included with the permeate. In the fresh version of the cream soup, the panelists ranked the salty taste of the permeate sample as being slightly lower than the 50% salt sample. Also, in the retorted soup, the permeate sample was ranked statistically not different than the 50% salt sample.

According to the FDA labeling laws, a “reduced-sodium” product must have at least 25% less sodium than an appropriate reference food (Stehlin, 1993). After mineral analysis, the permeate soup samples for both recipes contained 11% and 19% as much sodium as the 100% salt soup samples. This is well below the 25% reduction of sodium needed to label a soup as reduced-sodium. Permeate may allow the consumer to still receive the full satisfaction of a full sodium flavored soup, while reducing sodium in their diet. Adams and Maller (1995) also concluded a product could be reduced in sodium successfully up to 50%. This research suggests with whey permeates as a substitute or at least a partial substitution, a reduced sodium product such as a cream soup, could be effectively reduced well below necessary requirements for FDA labeling laws to give the consumer the satisfaction of a full-flavored product.

It should also be noted there was a much larger concentration of potassium, magnesium, and calcium within the permeate soups, than any of the other samples. The current recommended intake of potassium is between 1600 to 2000 mg/d. The DASH diet promoted a higher intake of fruits and vegetables to increase the intake of potassium,

calcium, magnesium and other minerals (Champagne, 2006). If incorporated into industry, whey permeates could help salt-sensitive hypertensive patients with the struggles they may face keeping their sodium intake low.

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APPENDIX

Figure 12: Consumer Acceptance Scoring Ballot

Date: _____

Name _____

By signing above, you agree to participate in this panel, and are not allergic to any dairy products.

Sample # _____

Overall Liking

Dislike
Extremely

Neither Like
nor Dislike

Like
Extremely

1 2 3 4 5 6 7 8 9

Saltiness level

Not salty

Too Salty

1 2 3 4 5 6 7 8 9

Amount of Salt

Not Nearly
Much

Not

Just

Too

Salty Enough

Salty Enough

About Right

Salty

Too Salty

What, if anything, did you like about the sample?

What, if anything, did you dislike about the sample?

Figure 13: Consumer Acceptance Panel Demographic Questions
Questionnaire

1. Gender: Male Female
 2. Age 20-25 26-30 31- 34 35-39 40-45 46-49 50-54 55-60 65-70 76-80
 81-100
 3. Primary household shopper? Yes No
 4. What influences your shopping purchases?
Please circle all that apply:

 Nutrition Price Brand Sodium content
 5. What is your knowledge of sodium containing foods and health?
Please circle one:

 Very Knowledgeable Somewhat knowledgeable Not Knowledgeable
 6. How often do you consume creamy soup?
Please circle one:

 Daily Few times a week Few times a month Few times a year

 Do not consume
 7. What brands?
Please circle one:

 Store Campbell's Progresso Snow Other brand
 8. Do you purchase reduced sodium or 25% less sodium? Yes No Don't know
 - If no, why not?
-
-