

## ABSTRACT

JIANG, YU. Whey Permeate or Yeast-digested Whey Permeate Used as Salt Substitute in Smoked Sausage to Lower Sodium. (Under the direction of Jonathan C. Allen.)

Whey permeate (WP) from ultra-filtration of whey and milk is considered a low-price by-product in cheese and whey protein production. The majority of the whey permeate is lactose but it also contains some fat, moisture, soluble non-protein nitrogen and minerals. Whey permeates can provide various minerals that help in giving a salty taste even if sodium content is low. High sodium intake is considered as a major factor that leads to more prevalent hypertension and other diseases in modern society. Food companies are looking for salt substitute that will lower the sodium within products. Whey permeate was viewed as nothing more than a waste product in the past. Previously, whey was used as animal feed while some whey was also spread onto the land to make field much more loamy. With increasing demands for cheese production there will be more and more whey permeate available. So there is a demand to find new ways to utilize the whey permeate. The objectives of this study were to design a smoked sausage utilizing whey permeate as a salt substitute to decrease sodium and chloride content and increase potassium, calcium and magnesium contents, which might decrease hypertension risk. One powdered whey permeate from Agri-mark company and two yeast digested whey permeate powders from Green Yeast Corp. were analyzed with ICP for seven minerals (Na, K, Ca, Mg, Fe, Zn, Cl). The saltiness intensity of three different WP samples were determined using a trained descriptive panel (n=12) and used to calculate the equivalent concentrations of salt and permeate for salty taste in sausages. The samples were subsequently added into a basic smoked sausage formula,

substituting for 0%, 25%, 50% and 75% of salt. A consumer survey (n=100) was conducted to evaluate sausages with WP and without WP for overall liking, flavor, saltiness, sweetness, texture, firmness, and juiciness. Sausages made with 25% of whey permeate were found not significantly different than the 100% salt sausage in overall liking, flavor, saltiness, texture, firmness and juiciness ( $P < 0.05$ ). The WP sausages had lower water activity and pH than the 100% salt sausage. There was no significant difference in the deformability of the sausages ( $P < 0.05$ ). The economic analysis also showed the 25% WP sausages had larger profit potential, which is valuable to industrial manufacturers. All sausages made with whey permeate were lower in sodium and chloride contents and had higher potassium, calcium and magnesium levels. The whey permeate sausages had higher saltiness than the actual sodium content contributed to the taste, but not as high as predicted from the salty taste of the permeate in aqueous solution. This research showed the feasibility of using whey permeates as a salt substitute in meat products.

Whey Permeate or Yeast-digested Whey Permeate Used as Salt Substitute in Smoked Sausage to Lower Sodium

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 my further work.

## BIOGRAPHY

Yu Jiang was born on Nov 15th, 1986. She finished her high school and college in China and participated in a “3+X” exchange program between Zhejiang University and North Carolina State University. She started her graduate education in the Master of Microbiology at North Carolina State University during the fall of 2008. She soon realized her passion for nutrition and transferred to the Interdepartmental Nutrition Program and got her Master of Nutrition degree in May, 2010. After graduation, she continued for a Master of Science in Food Science. She worked for Dr. Jonathan C. Allen in his food and nutrition laboratory for 2 years as a graduate student, and appreciates all she has learned from her experience working with the graduate students and research technicians in the laboratory. She wants to become a food safety inspector or R&D scientist in the future.

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# Literature Review

## 1. Salt Intake

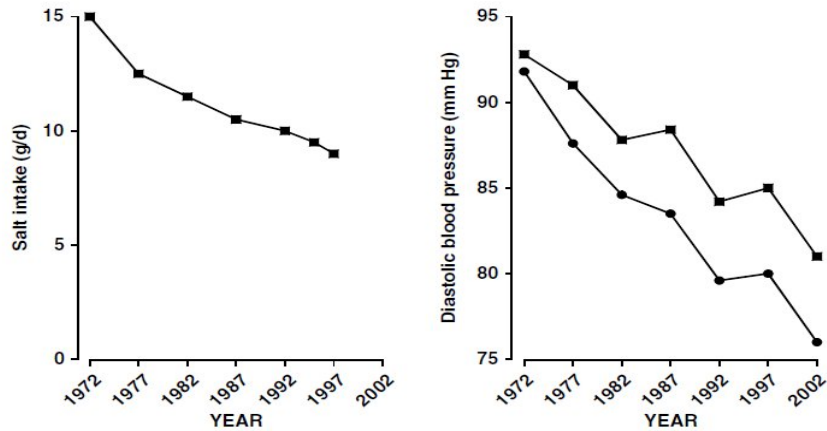
Salt is one of the most common and oldest food seasonings in the world. It is a colorless or white crystalline solid composed primarily of sodium chloride. Salt not only provides the saltiness taste, but also is essential for all animals' and some plants' lives. But salt will be harmful to animals and plants if taken in excess. Besides, salting is one of the most ubiquitous and important methods of food preservation. Synonyms for sodium chloride are common salt, table salt, or rock salt (Wikipedia, 2010). Salt is normally obtained from sea water or rock deposits. Three kinds of salts are normally used for human consumption: unrefined salt (such as sea salt), refined salt (table salt), and iodized salt (Wikipedia, 2010).

Sodium and chloride ions, the two major components of salt, are needed by all known living creatures in small quantities. Sodium and chloride are needed to maintain extracellular volume and serum osmolality, which are essential for maintaining homeostasis. They are also important for maintaining the membrane potential of cells and for active transport of molecules across cell membranes (Karppanen et al., 2005), which keeps muscles and nerves running smoothly. Results of observational studies and clinical trials document an association between salt (sodium chloride) intake and blood pressure (Kotchen and Kotchen, 1994). Blood pressure rises with age and hypertension prevalence among populations is proportional to salt supply.

## 1.1 Sodium

The Institute of Medicine defined the UL for sodium intake as 2,300 mg/d and the AI as 1,500 mg/d (Panel, 2005). In the United States, people consume near or even more than the tolerable upper intake level of 2,300 mg/d. That equals about 6 grams of salt (sodium chloride). The average current sodium intake is 3000–4500 mg/day in various western communities (Karppanen, et al., 2005). The high amount of sodium intake may be due to dietary sodium which comes from three main sources: sodium naturally present in certain foods, salt added during food processing and salt added at the table or in cooking, since sodium chloride is added to foods as a preserving agent and also used to provide flavor and texture. Excess dietary Na intake may result in increasing of body water weight, extracellular fluid volume, plasma volume and total exchangeable sodium, which all contribute to hypertension (Karppanen et al., 2005).

So, it seems that reducing use of sodium chloride is desirable. For example, unlike in most other countries, in Finland, a progressive and marked decrease in the average intake of salt has taken place during the past three decades. During this period, there has been a remarkable (10 mm Hg) fall in the average diastolic blood pressure of the population (Figure 1). The findings in Finland are consistent with an overall beneficial effect of a comprehensive population-wide sodium reduction (Karppanen et al., 2005).

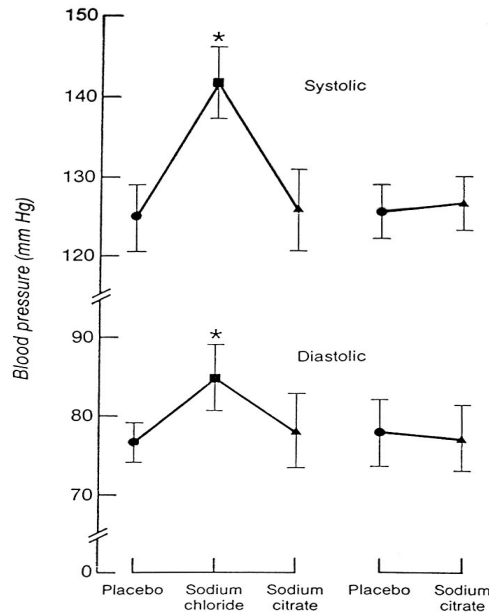


*Figure 1. Decrease of Salt Intake, and Lowering of the Population Blood Pressure in Finland (Karppanen et al., 2005)*

However, recent research indicated that all the efforts in the United States over the past 3 decades have had no effect on the population's sodium intake (McCarron et al., 2010). The Harvard researchers analyzed data from 38 studies that were conducted between 1957 and 2003 that included 26,271 participants. In each study, participants' sodium intake was monitored by recording levels of 24-h urinary sodium (UNaV). Results showed that there was no significant change in urinary sodium, which means no indication that sodium consumption increased over that time (Bernstein and Willett, 2010). Another analysis involved 19,151 people from 33 countries and 62 survey sites between 1984 and 2008 also revealed no evidence of a sodium intake change over time (McCarron et al., 2010). The researchers estimated that the mean sodium intake from 1957 to 2003 remained at 3,700 milligrams per day constantly, which was much higher than the current federal dietary guidelines at 2,300 mg per day (Bernstein and Willett, 2010). The failure of the government's efforts has been typically attributed to the food industry's excessive use of sodium in their products.

## 1.2 Chloride

There is another concern that maybe it is not sodium but the chloride, which contributes more to increase the risk of hypertension. The IOM set an AI and UL for chloride on an equi-molar basis to that of sodium since most sodium is consumed in the form of sodium chloride (USDA, 2005). The degree to which the sodium is responsible for increase in blood pressure is controversial. Animal studies comparing multiple forms of sodium with sodium chloride show the real cause may be chloride because blood pressure tended to fall with the reduction of sodium chloride and not with other forms of sodium from the diet, such as sodium citrate, or sodium phosphate (Kurtz et al.1987). A research experiment was carried out to determine if ingestion of extra sodium chloride (240 mmol of sodium per day) would increase blood pressure in five hypertensive male patients. After about 3 days of consuming the extra sodium chloride (5.5 g/day) in the form of capsules, the average systolic pressure went from 126 mm Hg to 142 mm Hg and the average diastolic pressure went from 76 mm Hg to 84 mm Hg. However, changing the content of the capsules to dextrose (placebo) or sodium citrate (240 mmol of sodium/day) reversed the increase caused by the sodium chloride (Figure 2). Therefore, we can conclude that the chloride ion may play an important role in inducing hypertension (Kurtz et al., 1987).



*Figure 2. Effects on Blood Pressure of Supplementing Dietary Sodium with Sodium Chloride and Sodium Citrate in Five Men with Essential Hypertension (Kurtz, et al., 1987)*

However, because most of the dietary chloride that is absorbed accompanies dietary sodium absorption, chloride is regulated indirectly through sodium intake. So less sodium intake also can lead to less chloride intake and then help to reduce risk of hypertension. However, these studies suggest that more research is needed to determine whether chloride salts with other cations are effective salt substitutes for lowering hypertension risk.

## **2. Diseases Caused by High Sodium Intake**

High-salt diets are linked to a number of health problems. High blood pressure, or hypertension, affected about 28.6% of the U.S. population between 1999–2002, which

means one in four adults are affected (He and MacGregor, 2009). Only about one third of all hypertensives are controlled in the United States.

The normal blood pressure of humans is less than 120/80 mm Hg (Mancia et al., 2007). Individuals with systolic blood pressure 120–139 mm Hg or diastolic blood pressure 80–89 mm Hg are considered prehypertensive, and individuals with systolic blood pressure more than 140 mm Hg and/or diastolic blood pressure more than 90 mm Hg are considered to have hypertension (Mancia et al., 2007). Systolic blood pressure is measured when the heart contracts and pumps blood. Diastolic blood pressure is the one when the heart rests between heart beats.

Overall, the worldwide burden of hypertension in 2000 was estimated to be 26.4% of the adult world population, with 333 million in developed and 639 million in developing countries (Kearney et al., 2005). Although there is a larger affected population in developing countries, hypertension is more prevalent in developed countries, especially in United States (Hajjar and Kotchen, 2003). An analysis of NHANES data in US adults between 1999 and 2004, hypertension prevalence increased from 26.8% to 29.3% (Ong et al., 2007). It has been estimated that by 2025, 1.56 billion individuals will have hypertension, an increase of 60% from 2000 (Kearney et al., 2005). In general, hypertension prevalence is high in all surveyed countries with a range from 20% to almost 50% (Wolf-Maier et al., 2003). Programs that improve hypertension control rates and prevent hypertension are urgently needed.

High blood pressure also contributes to a series of cardiovascular diseases that includes stroke, heart failure, myocardial infarction, renal insufficiency/failure, peripheral

vascular disease, retinopathy, dementia, and premature mortality. Gu et al. demonstrated that hypertension can be induced by a prolonged high-salt diet and that it is associated with increased renal injury in normal Sprague-Dawley rats (Gu et al., 2008; 2009). Furthermore, high blood pressure could be linked to osteoporosis by increasing calcium excretion in the urine in association with high salt intake and excretion. A recent study performed in 94 primary hypertensive children, aged 6 to 18 years, suggested that the adolescents had increased fat mass and an imbalanced relationship among bone weight, fat mass, and lean body mass, with bone weight lower than expected in the girls (Pawel et al., 2008).

### **3. High Risk Populations**

Some Americans, such as older Americans and African Americans, are at a particularly high risk from high blood pressure. African Americans are generally more susceptible to hypertension. First, traditional African American foods are often high in salt (Smith et al., 2006). Second, they are inherently pre-disposed to high blood pressure due to genetic factor (Hunt, 1998).

The morbidity rate in this group is also very high, nearly 35% (Calpurnyia et al., 2007). Hypertension will affect them at a relatively early age and they are 80% more likely to die from a stroke on account of the condition. They are also vulnerable to heart disease and kidney failure (Karanja et al., 2007).

Some women will experience gestational hypertension during pregnancy. High blood pressure during pregnancy can be harmful to the health of both the mother and the

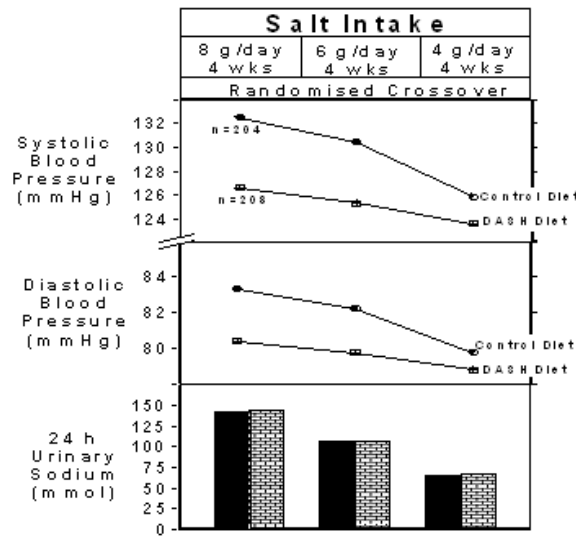
fetus. Low salt intake will help to prevent hypertension during pregnancy (Gibson and Carson, 2010).

#### **4. Dietary Approaches to Stop Hypertension (DASH)**

The DASH diet (Dietary Approaches to Stop Hypertension) is a diet promoted by the National Heart, Lung, and Blood Institute to control hypertension. This eating plan is rich in fruits, vegetables, whole grains, and low-fat dairy foods; it includes meat, fish, poultry, nuts and beans; and it is limited in sugar-sweetened foods and beverages, red meat, and added fats (Champagne, 2006). There are several eating plans included in the diet, with the daily caloric intake ranging from 1699 to 3100 dietary calories. In addition to its effect on blood pressure, it is considered a well-balanced approach to eating for the general public. It is now recommended by the U.S. Department of Agriculture (USDA) as an ideal eating plan for all American (Sacks et al., 2001).

The DASH diet reduced systolic blood pressure by 6 mm Hg and diastolic blood pressure by 3 mm Hg in patients with normal blood pressure, and dropped blood pressure by 11 mm Hg and 6 mm Hg in a hypertensive group, respectively. One recent study showed changes in blood pressure and 24-h urinary sodium excretion with the reduction in salt intake (from 8 g/day to 4 g/day for 4 weeks) in all participants (hypertensives: n=169; normotensives: n=243) when comparing the normal American diet (i.e. control diet) and the DASH diet (Sacks et al., 2001).

**DASH-Sodium Trial (N.I.H.)**  
**All participants (N = 412)**



*Figure 3. Changes in Blood Pressure and 24 h Urinary Sodium Excretion with the Reduction in Salt Intake in All Participants (Hypertensives: n=169; Normotensives: n=243) on the Normal American Diet (i.e. Control diet) and on DASH Diet (Sacks et al., 2001)*

But there are two limitations for the DASH diet. The DASH can't supply enough iodine to the human body since iodized salt is an important source of dietary iodine. Moreover, the relatively high protein level of the DASH diet may cause problems in patients with hypertensive neuropathy or renal dysfunction, because protein overload may further compromise renal function and aggravate hypertension (Fouque and Aparicio, 2007).

## 5. Physiology of Salty Taste

Saltiness is a taste produced best by the presence of cations (such as  $\text{Na}^+$ ,  $\text{K}^+$  or  $\text{Li}^+$ ) using ion channels located in the apical membrane of certain cells in taste buds (Avenet and Lindemann, 1991). Other ions of the alkali metal group also taste salty, but

the less sodium-like the ion is, the less salty the sensation. The cations, such as  $\text{Na}^+$ , are transported into the taste cells through apical-localized cation channels. Then they are extruded by basolaterally located  $\text{Na}^+\text{-K}^+\text{-ATPases}$ ;  $\text{Cl}^-$  is transported from the apical to the basolateral side, possibly via a paracellular route, at the same time (DeSimone et al., 1984). Thus, it is likely that the selective anion permeability of the tight junctions contributes to the distinct taste of various sodium salts (Elliott and Simon, 1990). As the size of potassium ions is close to that of sodium, they taste similar to sodium salt.

## **6. Current Salt Substitutes**

Salt substitutes are low-sodium table salt or processing alternatives that aim to lower the risk of high blood pressure and cardiovascular disease associated with a high intake of sodium chloride while maintaining a similar taste (Bugge, 2010).

### **6.1 Chemical Salt Substitutes**

Most salt-free substitutes contain potassium instead of sodium, yielding potassium chloride (Desmond, 2006). Potassium lactate may also be used to reduce sodium levels in meat and poultry products. Another way to reduce salt intake 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), but it does contribute sodium to the product.

Potassium chloride may have a metallic taste (Desmond, 2006). Potassium salt substitutes are readily available at most grocery stores in the spice section, such as No-salt or Also-salt. But most salt substitutes are made of a mixture of sodium chloride and

potassium chloride and are more popular because the mixture helps to reduce the bitter taste contributed by potassium chloride (Desmond, 2006). These salt substitutes aren't sodium-free, but they create a reduced salt product that's made of a combination of sodium and potassium chlorides. These products usually have much less sodium, but have a more realistic salt flavor. For instance, Morton Lite Salt™ contains a 1:1 ratio of sodium chloride and potassium chloride (Karahadian and Lindsay, 1984).

However, various diseases and medications may decrease the body's excretion of potassium, thereby increasing the risk of potentially fatal hyperkalemia. People with kidney failure, heart failure or diabetes should use salt substitutes carefully (Bugge, 2010).

## **6.2 Natural Salt Substitutes**

Soy sauce is one of the world's oldest condiments and has been used in China for more than 2,500 years (Anderson et al., 2010). It is made either by fermenting soybeans with *Aspergillus oryzae* and *Aspergillus soyae* molds or by an artificial acid hydrolysis chemical process (Lioe et al., 2010).

The basic recipe consists of salt, soybeans or roasted grains, water and microorganisms. Soy sauce has been used to enhance the flavor profiles of food, such as seafood. It tastes sweet, sour, salty, and bitter. It also has a unique umami flavor which helps to enhance the flavor and the soy extract helps to blend and balance taste (Kremer et al., 2009). The salt is not just added for flavor; it also helps establish the proper chemical environment for the lactic acid bacteria and yeast to ferment properly. The high salt concentration (12-18%) is also necessary to help protect the finished product from

spoilage. Low-sodium soy sauces are produced, but it is difficult to make soy sauce without using some quantity of salt as an antimicrobial agent (Anderson et al., 2010). So, it's not actually a very good choice for salt replacement.

A project conducted in UK also found that seaweed granules could be alternatives to salt without affecting the shelf life and taste of the product. The seaweed granules are manufactured from cold water brown seaweed that contains about 3.5% sodium (Daniels, 2008). The details for the manufacturing process have not been published.

## **7. Whey Permeate**

### **7.1 Definition of Whey Permeate**

Whey permeate, which is a by-product of the cheese making process, is a kind of white to light cream-colored powder or liquid with a bland odor and flavor. Whey permeate was defined by US Dairy Export Council in 2004 as “a source of dairy solids obtained by the removal of protein, some minerals and lactose from whey” (USDEC, 2004). It also has been identified as deproteinized whey, dairy product solids, modified whey, reduced protein whey, or permeate. Whey permeate was viewed as nothing more than a waste product in the past. Some whey is used as animal feed while some is also spread onto the land to make fields much loamier (Dixon, 2008). Now, whey permeate also finds application in the foods like bakery products, beverages, chocolate, etc.

### **7.2 Production of Whey Permeate**

Whey permeate is derived from milk. The supernatant from cheese production is called whey, a yellowish liquid containing almost 95 % water, and the rest being lactose,

minerals, and two soluble proteins lactalbumin and lactoglobulin (USDEC, 2004). First, liquid whey is drained off of the curd and “For every 1 pound of cheese produced, 9 pounds of liquid whey results” (Parmentier, 2000). Then the liquid whey goes through a process called ultrafiltration in which the liquid whey is forced through a filter membrane with narrow pores. The whey proteins will be retained by the membrane while other small molecules like lactose, minerals and water will pass (Walstra, 2006). The filtration step generates the protein portion which is then dried to yield Whey Protein Concentrate (Figure 4). The liquid filtrate portion is considered the liquid whey permeate, a yellowish liquid that is also mostly water, with some lactose and minerals. Finally, the lactose in the unprocessed liquid whey permeate can be removed through crystallization to make pure white lactose crystals (USDEC, 2004). This operation also yields what is called de-lactosed whey permeate, containing lactose and a high amount of minerals. Whey permeate and de-lactosed whey permeate can be condensed and dried to a powder. The solid whey permeate is easier to package and transport than the liquid whey permeate.

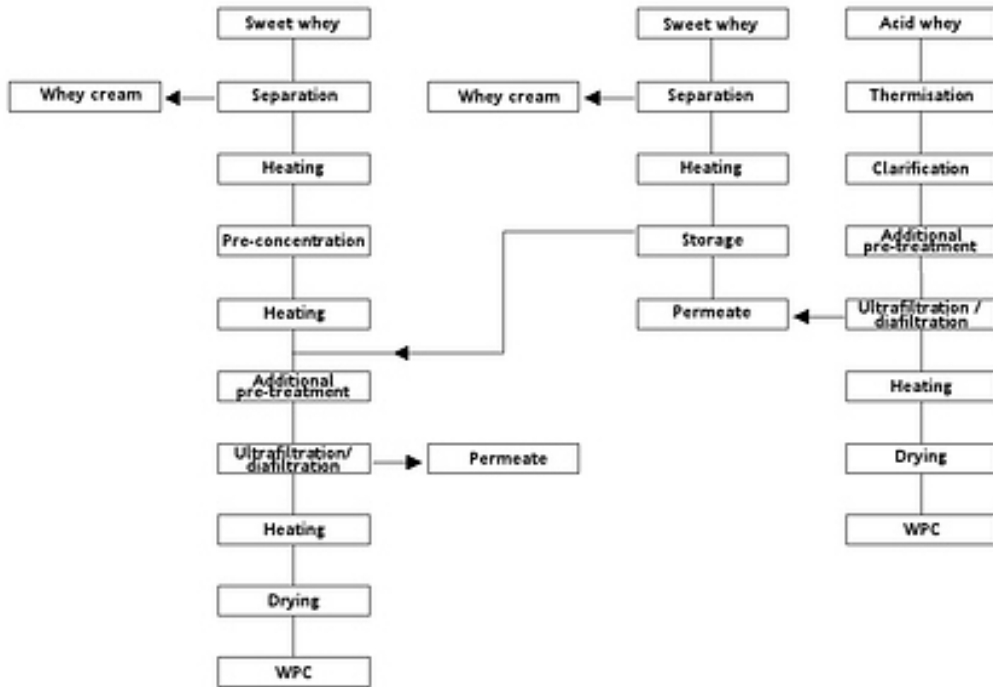


Figure 4. Flow Chart of Whey Permeate Production (USDEC, 2004)

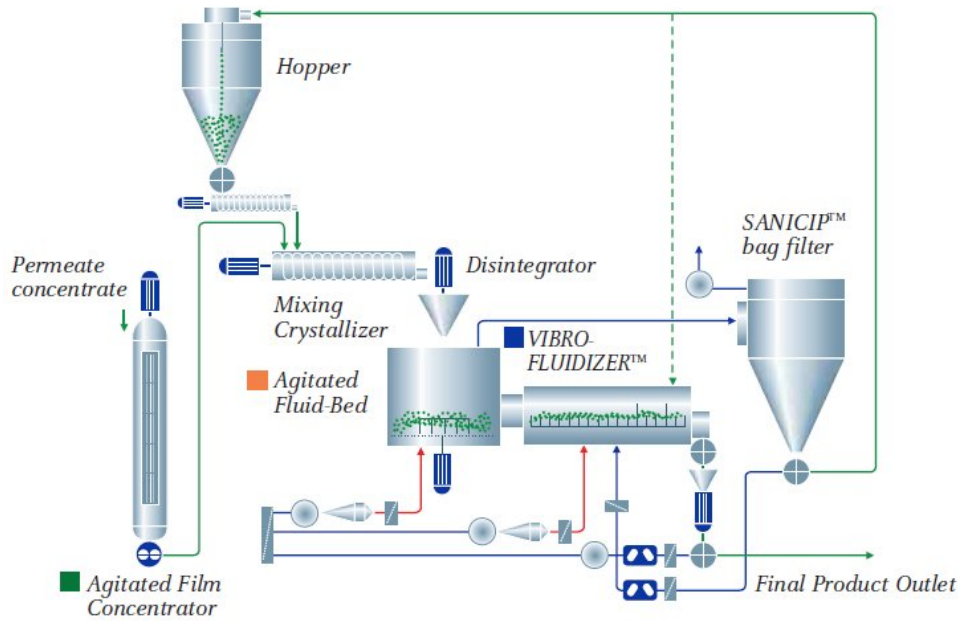


Figure 5. The TIXOTHERM™ Process (Patented) (GEA, 2010)

The GEA company recently founded a more efficient way called the TIXOTHERM™ process to produce whey permeate. This process can convert the liquid whey permeate into a first-class non-caking powder product using less energy. The TIXOTHERM™ process is a four-step process (GEA, 2010). First, the whey permeate is evaporated in a falling film evaporator to 60% TS. Then it is pumped to a vertical agitated film high concentrator to be further concentrated, about 85% TS. The next step is using the mixing crystallizer to get a rich lactose crystal semi-solid with a friable texture ideal for the following fluid bed drying and cooling. Finally, the remaining moisture is evaporated in an agitated back-mix fluidized bed followed by final drying and cooling in a plug flow VIBRO-FLUIDIZER®. The drying air for the bag mix and plug flow fluid bed is exhausted through a SANICIP™ bag filter, from where the collected fines particles are returned back to the mixing crystallizer (GEA, 2010).

The final powder has a higher degree of crystallized lactose than achieved by the traditional method, and the total moisture content is approximately 2%. The powder is non-hygroscopic and non-caking. Energy consumption is reduced by more than 30 %, and building requirements are reduced by more than 50%. It can produce up to 7,500 kg/hr final powder and process 3,000,000 liters of whey permeate/day. It's an efficient new way to put a greater range of dairy by-products to more profitable use (GEA, 2010).

### **7.3 Whey products**

Whey is a yellow or white dilute liquid which comes from cheese-making and casein production. Liquid whey contains approximately 93% water and 0.6% protein

(Huffman, 1996), 0.05% fat, 0.7% ash, and 4.9% lactose (Smithers et al., 1996). From its source and processing technique, it can be divided into delactosed whey, demineralized whey, acid whey and sweet whey.

De-lactosed liquid whey is produced by removing lactose by crystallization. Lactose concentration can be reduced by hydrolyzing the lactose into glucose and galactose by adding galactosidase (Smithers et al., 1996). Demineralized whey must have an ash content lower than 7%. It is produced by demineralization and drying liquid whey to remove a portion of the mineral content. These two kinds of whey are usually used in infant and dairy foods, dry blends and bakery fields (ADPI, 2003). Acid whey has a pH of 5.1 or lower and is produced during the manufacture of cottage and ricotta cheeses. Acid whey may be used in salad dressings and snack foods (ADPI, 2003). Sweet whey has a pH of 5.5 or greater and is created during the manufacture of rennet-coagulated cheeses such as Cheddar or Swiss (ADPI, 2003).

Fortified blended foods (FBF) are typically made of corn soy blend, and used as food aid for millions of people worldwide, especially malnourished individuals and vulnerable groups. Adding whey to FBF improves the protein quality, allowing a reduction in the total amount of protein, which could have potential metabolic advantages. It also allows for a reduced content of soy and cereal and thereby a reduction of potential antinutrients. Bioactive factors in whey might have beneficial effects on the immune system and muscle synthesis (Hoppe et al., 2008).

Whey protein concentrate (WPC) is the retentate remaining on the membrane of the ultrafiltration process in which liquid whey is forced through a membrane. The

proteins are spray-dried and concentrated into solid powder (Huffman, 1996). According to the level of whey protein (34% and 89%), there are different kinds of WPC. WPC35 contains 35% protein, 53% lactose, 4% fat and 8% ash, which is similar to non-fat dry milk. WPC50 contains 50- 53% protein, 35% lactose, 5% fat and 7% ash. WPC80 contains 80% protein, 7% lactose, and fat and around 4-7% ash (Huffman, 1996; Pasin, 2000). Whey protein concentrates (WPC) are used as emulsifying, thickening and gelifying agents and as a stabilizer in foods (Mann, Ernest, 2000). It is used for fat substitution in some desserts because of its good emulsifying property.

Another whey product is whey protein isolate (WPI), which contains 90% or more protein, 1% fat, 1% lactose and 3% ash (Luhovyy et al., 2007). WPI is usually produced in a process similar to WPC but with two more steps: a microfiltration process that reduces the fat content and lactose hydrolysis to remove lactose. But it can also be processed by pretreating the whey with an ion exchange system before the ultrafiltration process.

Whey proteins and amino acid supplements have a strong position in the sports nutrition market based on the purported quality of proteins and amino acids they provide. Recent studies demonstrated that whey proteins can promote whole body and muscle protein synthesis. Many bioactive components can be derived from whey to modulate adiposity, and to enhance immune function and anti-oxidant activity (Ha and Zemel, 2003). Whey protein may contribute to the regulation of body weight by providing satiety signals that affect both short-term and long-term food intake regulation. Whey protein affects satiation and satiety because: (1) whey protein fractions are insulinotropic;

(2) bioactive peptides affect the renin-angiotensin system; (3) amino-acids released after digestion activate many components of the food intake regulatory system; (4) whey protein and/or peptides and/or amino acids interact with other milk constituents (Luhovyy et al., 2007). Because whey is an inexpensive source of high nutritional quality protein, people are more focused on whey these days. Therefore, whey protein may be a good source of physiologically functional food for persons with obesity and its co-morbidities (hypertension, type II diabetes, hyper- and dislipidemia) (Bohdan et al., 2007).

Whey permeate is the supernatant liquid that passed through the filtration membrane (Chandan et al., 1982). It contains primarily lactose, about 75-85% for the solid whey permeate and 4.8% for the liquid whey permeate (Macedo et al., 2002). Almost all protein, fat and colloidal salts are excluded through the ultrafiltration step. Only lactose, minerals, water-soluble vitamins and non-protein-nitrogen are retained in the liquid whey permeate (Fitzpatrick and O’Keeffe, 2001; Geilman et al., 1992). Liquid whey permeate contains mostly water and some minerals (0.5%). The solid whey permeate has high mineral level, about 6.35-8.6%. The mineral content of the permeate is comprised of sodium, potassium, calcium, magnesium, chloride and inorganic phosphorus (El-Salam et al., 1985).

The table below indicates the nutrient components of various whey types.

*Table 1. The Nutrient Components of Various Whey Types (Posati, Orr, 1976; Smithers et al., 1996; Allen, 2002 )*

	Protein%	Lactose%	Fat%	Ash%	Moisture%
Sweet Whey	12.9	74.4	1.1	8.4	3.2
Acid Whey	11.7	70.0	0.5	10.8	3.5
WPC35	36.2	46.5	2.1	7.8	4.6
WPC50	50.0	35.0	5.0	7.0	3.0
WPC80	81.0	3.5	7.2	3.1	4.0
WPI	91.5	0.8	0.5	3.7	3.7
Whey Permeate	4.0	75.0	0.5	8.5	12.0

#### **7.4 Characteristics of Whey Permeate**

Whey permeate consists primarily of lactose in a water solution with various minerals and soluble nitrogen (Fitzpatrick and O’Keeffe 2001). Compared to other whey products, whey permeate has a very low protein content of 3.0-8.0% and most permeates contain a high percent of lactose of 65-85% (USDEC, 2004). Whey protein concentrate (WPC) contains between 34% and 89% protein and whey protein isolate (WPI) contains 90% or more protein, while most whey permeate sold today has a composition of about 4% “protein”, 75% lactose, 0.5% fat, 4% moisture, and 8.5% ash (Allen, 2002). The main difference between these ingredients is the amount of protein. Fat content in permeate is very low so there is no added functionality from the fat (Allen, 2002). Whey permeate contains primarily non-protein nitrogen compounds like urea, creatine, creatinine, uric acid, orotic acid, and ammonia because most of the proteins are removed by the ultrafiltration process (Fitzpatrick and O’Keeffe 2001). However commercial products will label this non-protein nitrogen as true protein (Fitzpatrick and O’Keeffe 2001). So, the main nutritional value of the whey permeate comes from lactose and minerals.

### **7.4.1 Lactose**

Lactose is a disaccharide consisting of galactose and glucose, which form a  $\beta$ -1 $\rightarrow$ 4 glycosidic linkage. It forms small white crystals and plays an important role in milk. Technically speaking, one could use whey permeate in many of the applications where lactose is used. Baked products like breads, crackers, cookies, snacks, and sweet goods will benefit from the browning that permeate lactose contributes (Kimberlee, 2005). The lactose also helps to retain some moisture, and reduce sweetness in desserts (Kimberlee, 2005). A recent study also indicates that whey permeate can be used in flavored yogurt. People could not detect any sensory difference until 25% to 30% of the sucrose was replaced by whey permeate (Jaros, 2008). Although whey permeate lactose can be used in so many ways, it still has limited uses primarily because the lactose has low sweetness, low solubility and low digestibility by many people. However, hydrolysis of the lactose into glucose and galactose can enhance the sweetness of the permeate and any permeate products (Beucler, 2004).

### **7.4.2 Minerals**

The mineral content of whey permeate is similar to whey. The ash contains calcium, inorganic phosphorus, magnesium and other valuable minerals. It is also comprised of sodium, and potassium in concentrations similar to that of skim milk (El-Salam et al., 1985). Meta-analyses of clinical trials have demonstrated that potassium supplements significantly lower both systolic and diastolic blood pressures (Whelton and He, 1999). The blood pressure-lowering effect is greater in persons consuming a high-salt diet (Grimm et al., 1990). In people with high potassium diets, both mean blood

pressure levels and the prevalence of hypertension tend to be lower than in people with low potassium intakes (Morris and Sebastian, 1995).

Similar to potassium, low calcium intake is also associated with an increased prevalence of hypertension (Harlan, 1995). Calcium can help to reduce prevalence of osteoporosis while magnesium helps to regulate blood pressure as an inhibitor of vascular smooth muscle contraction (Harlan, 1995).

## **7.5 Liquid vs. Solid whey permeate**

### **7.5.1 Liquid whey permeate**

The liquid whey permeate is the liquid residue from milk after the removal of cheese curds in the cheese manufacturing (USDEC, 2004). Liquid whey permeate contains electrolytes, sodium, potassium, magnesium, zinc and calcium which could be utilized in sports beverages. The human body will lose a lot of electrolytes (sodium and potassium) through sweat during heavy exercise or work. The mineral loss can cause convulsion, shock and even death (Karppanen et al., 2005). The sodium and potassium help to maintain the osmotic pressure of the extra- and intra-cellular fluid and the commercial sports beverages can replenish the lost ions quickly. Because liquid whey permeate is rich in these minerals, it can enhance the overall nutritional content of a food product that can use whey permeate as an ingredient.

### **7.5.2 Solid Whey Permeate**

Solid whey permeate is produced by the ultrafiltration of liquid whey and spray dried into powder. These white powders typically contain lactose, water, minerals, and a small amount of fat or protein (USDEC, 2004). Dried whey permeate is easier to handle but processing costs are higher compared to the liquid form.

The solid whey permeate is lower in sodium content compared to liquid whey permeate (Table 1). So using solid whey permeate to replace salt can decrease sodium and chloride intake while increasing potassium, calcium, and magnesium amounts in the diet at the same time. Scientists want to decrease salt intake because in our modern world, the average current sodium intake is 3000–4500 mg/day in various westernized communities, which exceeds the tolerable upper intake level of 2,300 mg/d (USDA, 2005). A recent study conducted by NC State University investigated whey permeate as a salt substitute in fresh and retorted cream-based soups. The results indicated whey permeate formulated soups contain 19% and 11% as much sodium as the full-salt recipes, respectively (Dixon, 2008). The author concluded that whey permeate can be used as a salt substitute to reduce sodium intake.

Table 2. Analyses of Whey Permeates Expressed on A Dry Matter Basis (Dixon, 2008)

	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										
<b>Company A</b>	30.1	8.6	31.1	1.04	2.10	0.078	0.337	3.52	198.5	7.04
<b>Company B</b>	65.5	23.0	83.0	2.07	3.70	0.121	0.655	3.71	N.A.	6.68
<b>Company C</b>	66.1	30.4	47.1	2.15	4.78	2.003	1.706	0.91	251.5	10.30
<b>Company D</b>	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)
<b>Company E</b>	10.4	11.4	3.13	0.181	0.78	0.55	1.73	0.14	88	10.4
<b>Company F</b>	9.47	10.6	2.61	0.150	0.71	6.72	5.28	1.02	81	9.47
N.A. = not analyzed										

## 7.6 Descriptive analysis of whey permeate

Descriptive analysis gives a complete sensory description of the test products and provides a basis for determining and quantifying the sensory characteristics, which helps to identify the ingredients (IFT, 1981).

Dixon (2008) conducted a descriptive panel to determine flavors and aromas of five whey permeates from different companies (Table 2). The powdered samples were prepared in a 10% solution (90% deionized water and 10% permeate). Flavor descriptors of cardboard, canned meat, fruity, nutty, and vitamin were used for the whey permeates. Canned meat, fruity, nutty, vitamin, sour, and brothy was given to aroma aspects. Sweet, sour, salty, umami, and brothy were rated in intensity.

Significant differences were observed among the six whey permeates. From Table 3, all the whey permeates had a salty taste rating between 1.23 and 3.80. References for salt (NaCl) were valued at 5 (0.7% ,7 grams per liter) and 8 (0.9%, 9 grams per liter) (Meligaard, 1991). The Company D permeate had the highest salty taste

but it also had a fruity, nutty and sour aroma. The company F permeate had the highest score of 3.12 for sweet taste, using sweet references with values of 2 (20 grams sucrose per liter) and 5 (50 grams sucrose per liter) (Meligaard, 1991). As mentioned above, Company A, C and D whey permeates were liquid and Company E and F were solid whey permeate powders. The solid whey permeates are more sweet than the liquid whey permeate because they contain more lactose. Company D also tastes most strongly for umami, brothy and sour.

*Table 3. Descriptive Panel Sensory Evaluation. Scores are Means of 10 to 12 Panelists on 2 Replication Days (Dixon, 2008)*

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

<sup>a,b,c</sup> 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

## 8. Yeast-Digested Whey Permeate

### 8.1 Definition of Yeast-Digested Whey Permeate

Yeast-digested whey permeate powder is produced by the Green Yeast Corporation in Montreal, Quebec, Canada, which manufactures lactic yeast biomass and

functional ingredients for animal health/nutrition and for human applications (Green Yeast, 2010).

The products are a yellow, high protein, nutrient-rich yeast powder that benefits animal or human health and also produces a clean effluent ready for reuse or disposal. The lactic yeast powder contains about 50% protein, 20 - 30 % minerals, including K, Ca, Na, Mg, and Cl. Nucleotides, such as IMP and GMP, in the yeast powder can enhance the flavor and give a umami taste similar to MSG (monosodium glutamate). So it is also being used for a MSG substitute since MSG is becoming less used in the food industry (Green Yeast, 2010).

## **8.2 Production of Yeast-Digested Whey Permeate**

The company takes the liquid whey permeate and uses it as a substrate to culture a particular type of lactic yeast: *Kluyveromyces marxianus*, which can metabolize the main types of carbohydrates: glucose, sucrose, lactose, and xylose (Green Yeast, 2010). The yeast consumes the lactose in the whey permeate and absorbs the minerals into the cells to help growth. Under anaerobic conditions, the yeast will transform the lactose into alcohol and carbon dioxide, so it has a sour and alcoholic smell. On the other hand, the yeast cells multiply rapidly and generate a high quality biomass containing up to 50% protein on a dry basis under aerobic conditions. The yeast cells collected are all dried and ground to get the final dark-yellow-colored powder (Green Yeast, 2010).

## **9. Current Study of Whey Permeate in Food**

Most of the permeate sold today is produced from sweet whey and has a composition of about 4% protein, 75% lactose, 0.5% fat, 4% moisture, and 8.5% ash (Allen, 2002). The primary non-protein nitrogen compounds contained in whey permeate are urea, creatine, creatinine, uric acid, orotic acid, and ammonia (Fitzpatrick and O’Keeffe, 2001). Because fat content in whey permeate is very low, there is no added functionality from the fat. The ash contains calcium, phosphorus, and other valuable minerals that contribute to the overall mineral profile of a food product.

On the other hand, most of the whey sold today is made of sweet whey with a composition of about 12% protein, 73% lactose, 1% fat, 4% moisture, and 8.5% ash. Because they have very similar composition (USDEC, 2004), it is not surprising that some companies today are marketing their permeate as a whey replacement. And the 75% lactose contributes to most of whey permeate mass, so there is no surprise that we can use permeate in many of the applications where lactose or whey are used. It is commonly treated as a “Whey and lactose replacer” (ADPI, 2003).

A look at the 2003 ADPI Utilization and Production Trends report shows that “food uses of lactose include infant formulas, confectionery industry, nutraceuticals, pharmaceuticals, special dietary use, prepared mixes, dairy industry, baking industry, and chemicals. Over 65% of the lactose is used for infant formula and confections. ADPI also lists the food uses for whey. They include dry blends and prepared mixes, the baking industry, the confectionery industry, margarine manufacturers, nutraceuticals,

pharmaceuticals, special dietary uses, soup manufacturers, institutional uses, and all others” (ADPI, 2003). So these are all potential food uses for permeate.

### **9.1 Dairy Applications**

Whey permeate can be used in the dairy industry as an extender for proteins and lactose of milk. The whey permeate can be used in dips, processed cheese food, cheese sauces, and ice cream in the dairy product area. A recent study also indicates that whey permeate can be used in flavored yogurt. People could not detect any sensory difference until 25% to 30% of the sucrose was replaced by whey permeate (Jaros, 2008).

Moreover, whey permeate may be an excellent source of oligosaccharides. Scientists identified 14 oligosaccharides in the whey permeate, half of which have the same composition as human milk oligosaccharides. These oligosaccharides could potentially be used as additives in infant formula and products for the pharmaceutical industry (Barile et al., 2009).

### **9.2 Bakery Application**

Lactose in the whey permeate can also confer browning characteristic to bakery products. Baked products like breads, crackers, cookies and snacks can benefit from the browning that whey permeate contributes. The browning enhances appearance, adds pleasant caramelized flavor by absorbing volatile flavor compounds and attractive synthetic and natural pigments (ADPI, 2003). It can also help to retain moisture. Since the relative sweetness of lactose is only 20 ~ 30% that of sucrose, whey permeate can also be used in icing, coatings, and non-chocolate candies to reduce sweetness and provide important crystallization characteristics (ADPI, 2003).

### **9.3 Savory Applications**

Seasoning mixes for meals and sauces, macaroni and cheese mixes, and seasoning blends for salty snacks could use permeate to help deliver the flavors while providing a clean dairy flavor for these savory applications (ADPI, 2003). These products might be good applications for the yeast-digested whey permeate mentioned above.

### **9.4 Sweetener**

Use of whey permeate is sometimes limited because the lactose has low sweetness, low solubility and low digestibility by many people (ADPI, 2003). However, hydrolysis of the lactose into glucose and galactose enhances the sweetness of the permeate and any permeate products (Rexroat and Bradley, 1986).

Researchers at NC State University investigated hydrolysis for design of a thirst quenching beverage utilizing whey permeate in 2004. In this research, hydrolyzed whey permeate and unhydrolyzed whey permeate were incorporated into a basic beverage formula, and were substituted for 0%, 25%, 50%, 75% or 100 % of the water content. Then 110 consumers evaluated beverages containing WP and commercial beverages for their overall acceptability, flavor liking and thirst quenching ability (Beucler, 2004). All drinks made with WP were higher in electrolyte content compared to the commercial sports beverages. Drinks made with hydrolyzed whey permeate were more similar to the commercial beverages in sensory properties than unhydrolyzed whey permeate beverages. Hydrolyzed beverages in which whey permeate was substituted for 25% or 50 % of water were acceptable to consumers and received similar scores in thirst-quenching ability, flavor and overall acceptability (Table 4). However, whey permeate-containing

beverages exhibited brothy and dairy-sour flavors, and the intensity of these attributes was directly related to the percentage of whey permeate added (Beucler, 2004). The study demonstrated a successful application of whey permeate.

*Table 4. Mean values of consumer acceptance of commercial and WP beverages (Beucler, 2004)*

	C3	C5	C6	C9	C10	C12	Control	U25	U50	H50	H75	U100	Water	LSD
Overall Liking	6.39	6.44	6.35	6.63	3.26	5.72	5.92	5.71	5.25	5.08	3.67	3.67	7.48	0.57
Appearance Liking	3.92	6.75	7.40	7.04	6.53	7.06	7.10	7.02	5.61	6.19	5.40	6.25	7.71	0.57
Mouthfeel Liking	6.47	6.96	7.06	6.66	4.37	6.49	6.80	6.35	5.84	6.13	4.86	5.44	7.57	0.56
Fruit Flavor Intensity	6.73	6.35	5.84	8.15	2.60	6.96	6.08	6.54	6.44	6.18	5.68	5.81	1.29	0.48
Fruit Flavor Liking	6.50	6.30	6.23	7.46	2.71	6.21	5.75	5.35	5.55	5.29	4.00	4.50	5.22	0.47
Sweet Intensity	6.95	6.42	6.20	6.34	2.33	5.63	6.61	7.17	7.43	7.23	6.94	7.14	1.51	0.62
Sweet liking	6.47	6.51	6.12	6.64	3.16	6.02	6.19	5.87	5.42	5.25	4.21	4.48	5.90	0.62
Thirst Quenching Ability	5.70	6.44	6.31	5.55	3.82	5.59	6.18	5.70	5.47	5.35	4.06	4.74	8.04	0.59
Thirst Quenching Liking	5.71	6.44	6.22	5.50	3.43	5.52	6.01	5.52	5.29	4.98	3.79	4.29	7.93	0.60

C3, C5, C6, C9, C10, C12 are commercial beverages. Control is experimental beverages made with no WP. U25, U50, U100 are beverages made with 25, 50 or 100% unhydrolyzed WP and H50 and H75 are beverages made with 50 or 75% hydrolyzed WP respectively.

## 9.5 Salt Substitute

If people can decrease sodium and chloride intake and increase potassium, calcium and magnesium intakes at the same time, it could result in a decreasing of hypertension risk, theoretically. Just as sodium and chloride contribute to high blood pressure, potassium, calcium and magnesium may have the opposite effects (Gelabert et al., 2003).

A recent study conducted at NC State University in 2008 tried to use whey permeate as salt substitute in fresh and retorted cream based soups. In the study, a trained sensory panel found salty taste for 13.3 g whey permeate powder to equivalent to 1 g NaCl in solution (Dixon, 2008). The group formulated a cream soup in which each gram of NaCl in the original recipe was replaced with 13.3 g of whey permeate powder. The

permeate-containing soup was compared with soups made with 0%, 50%, and 100% of the NaCl called for in the original recipe. The results indicated that the whey permeate soup was ranked in salty taste slightly lower than the fresh soup that had 50% of normal salt, although the permeate soup had only 19% as much sodium as the full salt recipe on a dry-matter basis. And in a similar trial with retorted soup recipes, the permeate soup was ranked slightly higher than the 50% salt soup, but with only 11% as much sodium as the full-salt recipe (Dixon, 2008). The author concluded that solid whey permeate powder could be a substitute for salt to reduce the sodium intake from soups.

For some people, a salt substitute can be a good option for adding flavor to food without adding sodium. And most substitutes on the market today are made of potassium chloride. However, too much potassium can be bad, too. In the human body, the excess potassium is excreted through the kidneys (Bugge, 2010). But people with kidney disease, diabetes, and heart failure may have problems eliminating potassium, which can lead to high potassium levels—hyperkalemia (Karppanen et al., 2005). In addition, the salt substitutes that contain potassium have a bitter and metallic flavor that makes the taste unappealing (Desmond, 2006). Some people may recognize it and return back to the table salt because it has better taste. But whey permeate may have better acceptance since it is natural and has a reasonable proportion of minerals. Solid whey permeate can give a dairy flavor to the food.

## **10. Smoked Sausage**

The manufacture of sausages began over two thousand years ago. Sausage is defined as ground meat mixed with fat, salt, other seasonings, and preservatives. A variety of meats can be used in the sausage; pork, beef, turkey, poultry are the most common sources of sausage making materials. The word “*sausage*” comes from the Middle English *sausige*, which came from *sal*, Latin for salt. In that ancient time, people did not have refrigeration to preserve their meat and so making sausage with salt was a good way to store the meat. Typically the sausage is formed in a natural (usually made of pig intestines) or synthetic casing (Filippone, 2010).

According to the cooking level, sausage can be divided into fresh sausage and cooked sausages. The fresh sausage needs to be cooked before consumption. Depending on the cooking methods, the cooked sausage can be further defined as dry or smoked forms. Dry sausages are cured sausages that are fermented and dried (Filippone, 2010). They can keep for a long time without refrigeration, such as salami and summer sausages. Smoked sausages are developed to help preserve the meat during the warmer months. The smoking process exposes the sausages to smoke and heat in a controlled environment. Although foods that have been hot smoked are often reheated or cooked, they need refrigeration for storage, but are typically safe to eat without further cooking.

### **10.1 Components in the Smoked Sausage**

Sodium nitrite cures the meat and causes the pink color in the meat. It also enhances the flavor that has become characteristic in sausage products. The nitrite, in combination with moisture, pH, added salt, and final internal processing temperature, has

a general bacteriostatic effect in the finished sausage product. It is needed in the sausage to inhibit the spoilage microorganisms such as *Clostridium botulinum*, *Clostridium perfringens* and *Staphylococcus aureus* (Bang et al., 2008). Since nitrites and nitrates can be toxic to humans, the use of these ingredients in sausage formulations is carefully controlled.

Ascorbic acid is a sugar acid with antioxidant properties. It is a white to light-yellow water-soluble crystal or powder. Ascorbic acid is the active form of vitamin C. Ascorbic acid is a reducing agent that reacts with nitrite to insure development of the desired color in cured sausage products. It is used to speed the curing process and stabilize the color of the final product (Cheng et al., 2011).

The phosphate salts used in sausage production are usually sodium phosphate, sodium triphosphate and sodium polyphosphate. These additives help retain moisture by raising pH, and cause myosin and actin to dissolve (Wongwiwat et al., 2010). It also interacts with sodium chloride to cause swelling or unfolding of the muscle proteins, thereby making more sites available for water binding. Incorporation of phosphate increased sausage firmness and cooking yield (Cheng et al., 2010). The phosphate can bind with  $\text{Ca}^{2+}$ , and  $\text{Mg}^{2+}$  to cause muscle structure to loosen. The phosphate salts also help to prevent fat or lipid oxidation. It is usually added in amounts of less than 0.5% by weight (Wongwiwat et al., 2010). BRIFISOL 512 is an agglomerated blend of sodium polyphosphates, designed to remain water-soluble and protein-effective even at very low processing temperatures and in the presence of salt. BRIFISOL 512 will disperse quickly

and evenly throughout the meat tissue, rapidly solubilizing the protein and thus effectively increasing moisture retention (BKGC, 2010).

Spices, such as garlic, are important contributors to sausage flavor and provide bacteriostatic and antioxidant properties. Typical spices used in various sausage products include black pepper, allspice, basil, bay leaf, cardamom, cloves, ginger, mace, nutmeg, mustard, paprika, pimento, cayenne pepper, white pepper, caraway, coriander, celery seed, cumin, marjoram, thyme, savory, sage, anise, cinnamon, capsicum, onion, garlic, sesame, and fennel (Zaika, 1988). If spices are treated with 7% salt solution, several compounds show greater antifungal activity (Shelef and Seiter, 1993).

Salt is very important in the sausage since it can improve flavor and salty taste. Most sausage formulations contain 1 to 3% salt. It also retards microbiological growth by forming brine with water, which helps to preserve the sausages. Chloride interacts with the phosphate to aid in solubilizing the myosin-type proteins of comminuted animal muscle so as to enable emulsification of the fat (Wongwiwat et al., 2010). Sodium and chloride bind with the protein and cause the structure to loosen, forming an actin and salt complex, helping to improve the water holding capability. Salt also "solubilizes" and extracts the muscle protein on the surface of meat particles. This semi-fluid protein film coagulates during heating, binding the meat particles together and producing a firm sausage texture.

## **10.2 Salt in Sausages Contributes to the Excess Dietary Sodium Intake**

The high salt in sausage recipes and processing may contribute to excessive dietary intake of sodium, a risk factor for hypertension in some individuals. A survey

carried out by the Food Standards Agency revealed that there was more salt in the standard pork sausages on sale in 2007 than those analyzed 12 years previously. The amount of salt in these products increased from 2.2 g to 2.4 g per portion (defined as two cooked sausages) since the last survey in 1991. One portion of pork sausages can contain more than a third of the maximum daily recommended sodium intake, which was 6 g per day at the time of publication (Food Standards Agency, 2003).

Many organic and inorganic salts have been evaluated in attempts to partially replace sodium chloride in the manufacture of sausage products (Gelabert, 2003). Unfortunately, most give unsatisfactory flavor characteristics to the sausage or detract from the emulsifying characteristics of the sausage formulation such that the fat/water content is adversely reduced during cooking. There is a real need to develop a salt substitute for sodium chloride in the production of sausage (Gelabert, 2003). Whey permeate should be investigated. First, it contains high levels of cations such as potassium and calcium that can contribute to salty taste. Second, there are non-protein nitrogen (NPN) components found in whey permeates that may cover some bitter flavor contributed by the cations (Harju, 2001). Finally, it is low-cost and can give a natural dairy flavor to the sausage.

## **Research Objectives**

1. Select whey permeate and yeast-digested whey permeate materials to investigate as salt replacers;
2. Select sausage formulations that meet research needs by being undesirably high in sodium;
3. Compare the whey permeate and yeast-digested whey permeate by a sensory panel and through mineral analysis to evaluate sodium, chloride, potassium, magnesium, zinc, iron, and calcium levels;
4. Evaluate saltiness of sausages in comparison with known concentrations of sodium chloride to make comparisons of permeate and table salt through trained panels;
5. Judge acceptance towards the use of whey permeate in smoky flavored sausages;
6. Measure physical properties by consumer testing of sausages, such as pH, water activity and deformability;
7. Measure mineral content of finished sausages to determine degree of sodium reduction and compliance with current labeling claims for “reduced sodium”, or “a good source” of potassium.

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Whey Permeate or Yeast-digested Whey Permeate Used as Salt Substitute in Smoked Sausage to Lower Sodium

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## Abstract

Whey permeate (WP) from ultra-filtration of whey is considered a low-price by-product in cheese and whey protein production. The most abundant component of the whey permeate is lactose but it also contains some fat, moisture, soluble non-protein nitrogen and minerals. Whey permeates contain various minerals that contribute to a salty taste even if sodium content is low. High sodium intake leads to more prevalent hypertension and related diseases in modern society. Whey permeate was often viewed as nothing more than a waste product in the past, but now is being sold as a food ingredient and potentially as a salt replacer. The objectives of this study were to design a smoked sausage utilizing whey permeate as a salt substitute to decrease sodium and chloride content and increase potassium, calcium and magnesium, which might decrease hypertension risk. One solid whey permeate and two yeast digested whey permeate powders were analyzed with ICP for content of 7 minerals (Na, K, Ca, Mg, Fe, Zn, Cl). The saltiness intensity of three different WP samples was determined using a trained descriptive panel (n=12) and used to calculate the equivalent concentrations of salt and permeate for salty taste in sausages. The samples were subsequently added into a basic smoked sausage formula, substituted for 0%, 25%, 50% and 75% of salt. A consumer survey (n=100) was conducted to evaluate sausages with WP and without WP for overall liking, flavor, saltiness, sweetness, texture, firmness, and juiciness. Sausages made with 25% of whey permeate were found not significantly different than the 100% salt sausage in overall liking, flavor, saltiness, texture, firmness and juiciness ( $P < 0.05$ ). The WP sausages had lower water activity and pH than the 100% salt sausage. There was no

significant difference in the deformability of the sausages ( $P < 0.05$ ). The economic analysis also showed the 25% WP sausages had lower ingredient cost. All sausages made with whey permeate were lower in sodium and chloride contents and had higher potassium, calcium, and magnesium levels. The whey permeate sausages had higher saltiness than expected from the actual sodium content, but not as high as predicted from the salty taste of the permeate in aqueous solution. This research confirmed the possibility of using whey permeates as a salt substitute in meat products.

Key Words: Whey permeate; yeast digested whey permeate; smoked sausages; sodium and chloride reduction

## **Introduction**

Whey permeate was defined by the US Dairy Export Council in 2004 as “a source of dairy solids obtained by the removal of protein, some minerals and lactose from whey” (USDEC, 2004). It is a by-product of the cheese making process and appearing as a white to light cream powder or liquid with a bland odor and flavor. During the production of one pound of cheese, approximately nine pounds of whey are produced (Parmentier, 2000). Whey protein concentrate (WPC) and whey protein isolates (WPI) are highly utilized in the food industry especially for muscle building applications, because they have high protein quality. Whey proteins can provide all essential amino acids that are needed by the human body. Whey permeate is the filtrate from ultrafiltration and microfiltration processing of liquid whey (Huffman, 1996). Historically, it was viewed as nothing more than a waste product. Whey and whey permeate has been used as animal feed for the high lactose content (Frank, 2001) while some is also spread onto the land making fields much more loamy. The liquid whey permeate is comprised primarily of 93% water, 5% lactose, 0.36% fat and 0.85% protein and 0.53% minerals (USDEC, 2004). Most solid whey permeate sold today has a composition of about 4% soluble non-protein nitrogen, 75% lactose, 0.5% fat, 4% moisture, and 8.5% ash (Allen, 2002). The non-protein nitrogen compounds consist of urea, creatine, creatinine, uric acid, orotic acid, and ammonia, which are not removed with the proteins by the ultrafiltration process (Fitzpatrick and O’Keeffe, 2001).

The major nutritional value of the whey permeate is contributed by the high content of lactose and minerals. Solid whey permeate powders were lower in sodium and chloride contents and had a higher potassium, calcium and magnesium levels than liquid whey permeate (Dixon, 2008). Sodium and chloride are needed physiologically to maintain extracellular volume and serum osmolality, which are essential for maintaining homeostasis. The high amount of sodium intake in the diet results in increasing body water weight, extracellular fluid volume, plasma volume and total exchangeable sodium which all contribute to hypertension (Karppanen et al., 2005). The degree to which the sodium is responsible for increase in blood pressure is controversial (Tanbeo, 1998; McCarron et al., 2010). Animal studies comparing multiple forms of sodium with sodium chloride show the real cause of hypertension may be chloride since blood pressure tends to fall with the reduction of sodium chloride and not with other forms of sodium from the diet, such as sodium citrate or sodium phosphate (Kurtz et al., 1987). So chloride ion may play an important role in inducing hypertension. However, most of the chloride absorbed comes from sodium intake in the form of sodium chloride (table salt), so we can regulate both of them at same time by lowering salt intake. Among other minerals in the whey permeate, calcium can help to reduce osteoporosis while magnesium helps to regulate blood pressure as an inhibitor of vascular smooth muscle contraction. The high potassium content in the whey permeate can also help to decrease risk of hypertension (Gelabert et al., 2003).

Yeast-digested whey permeate powder is a yellow, high protein, nutrient-rich yeast powder consisting of 50% protein, 9% moisture and 20 - 30 % minerals, including

K, Ca, Na, and Mg. The Green Yeast Corporation cultured a particular type of lactic yeast: *Kluyveromyces marxianus* (Green Yeast, 2010) that consumes the lactose in the whey permeate and absorbs minerals into the cells to help growth. Under anaerobic conditions, the yeast will transform the lactose into alcohol and carbon dioxide that causes the product to have a sour taste and alcohol smell. On the other hand, the yeast cells multiply rapidly and generate a high quality biomass containing up to 50 % protein on a dry basis under aerobic conditions. The manufacturing process collects the yeast cells, dries and grinds them to get the final dark yellow-colored powder (Green Yeast, 2010). The nucleotides in the yeast-digested whey permeate, such as IMP and GMP, can enhance flavor and give a umami taste that is similar to MSG (monosodium glutamate). Just as MSG can help to magnify the salty taste intensity, the yeast digested whey permeate can also be used as a sodium reducing agent.

Reducing sodium chloride in foods is desired to meet dietary guidelines (McCarron et al., 2010). Research in Finland showed a high decrease of average blood pressure with population-wide sodium reduction (Karppanen et al., 2005). Different salt substitutes were used, such as potassium chloride and potassium lactate, but none of them is a perfect salt replacer . For example, potassium chloride will introduce a metallic taste to the food at high use levels. However, whey permeate may help to improve this situation because whey permeate not only provides salty taste but also gives a fresh dairy flavor and sweet taste. And the price of whey permeate is low. Whey permeate might be a good salt substitute for use in the food industry.

The whey permeate has been used in thirst quenching beverages, corn syrup, and cream soup (Dixon, 2008). Research found that whey permeate can replace salt effectively in these foods. But no research had been done using whey permeate in meat products, a large potential market for whey permeate utilization. Whey permeate might benefit flavor and salt-reduction. Smoked sausages are sausages made with ground meat mixed with fat, salt, other seasonings and preservatives and undergoes smoking and cooking processes. Various kinds of meat can be used in the sausage. Pork, beef, turkey, and often poultry are the most common sources of sausage making materials.

The objectives of this study were, first, to compare whey permeate and yeast-digested whey permeate and select the appropriate WP for the subsequent experiments. The second objective was to replace salt partially with whey permeate to lower the sodium and chloride contents in the sausages. This aims to lower the risk of hypertension and associated diseases. Experiments were done to measure the physical properties and mineral contents of different WP-replacement level sausages. And the final task is to conduct a consumer panel survey testing the acceptance of these WP-containing sausages.

## Materials And Methods

### 11. Smoked Sausage Recipe

A smoked sausage recipe was obtained with ingredients as follows:

*Table 1. Ingredients for Smoke Sausages*

Ingredients	Amount
Ground pork	454 g (1 lb)
Sodium nitrate	0.93 g
Brifisol 512	2.25 g
L-Ascorbic acid	0.1 g
Salt	8.07 g
Whey permeate	0 g
Water	45 g
Ground Black pepper	1 g
Ground mace	0.5 g
Ground coriander	0.5 g
Ground yellow mustard	0.5 g
Garlic powder	0.5 g
Total	513.35 g

### Materials

The materials used in this research were obtained from different companies. Pork was from Nahunta Pork Center, Raleigh, NC; Salt was from Morton Salt Company, Chicago, IL; Brifisol 512 was from BK Giulini Corp., Simi Valley, California; Sodium Nitrate was from A. C. Legg, INC., Calera, AL; L-Ascorbic acid was from Sigma Chemical Company, Louis, MO; Whey permeate was from Agri-mark Corp., Lawrence, MA; Yeast-digested whey permeates were from Green Yeast Corp., Montreal, Quebec, Canada; Ground black pepper, ground mace and ground yellow mustard were from McCormick & Company, Inc., Hunt Valley, MD.; Ground coriander was from Spice Islands, Ankeny, IA; Garlic powder was from 5<sup>th</sup> Season, Raleigh, NC; Natural Casing:

Qual-a-tee “Custom Pac”, was supplied by Quality Casing & Netting Co. Inc., Hebron, KY.

## **Methods**

### **12. Production Process of Sausages**

#### **12.1 Small Batch Test of Pork Sausage Patties**

Ground pork meat was separated into 1 lb (454 g) blocks per treatment. The meat was mixed with other ingredients according to each treatment recipe. Meat was placed in foil containers and weighed. Then meat was baked in a 157 °C (315 °F) pre-heated oven 15 min to reach an internal temperature 71 °C (160 °F). The baked loaves were cooled and weighed.

#### **12.2 Industrial Processing**

Pork meat was ground with a 15 cm mold and separated into 4 groups of 30 lb (13620 g) each. Meat, salt, WP, and Brifisol 512 were mixed for 2 min in the same direction and then spice, sodium nitrate, and L-ascorbic acid were added and mixed for 3 more min with direction-change each minute. The mixture was stored in the refrigerator for 30 min (for the sodium nitrite reaction) and ground again with 8 cm mold. After cooling in the refrigerator for 1 hr, the mixtures were stuffed into natural casings and weighed. The sausages were put into the smoke room and processed with the following program (Table 2).

*Table 2. Operation Temperatures and Times for Hot Smoking and Cooking Procedure*

	Time (min)	Room temp ( °C )	Sausage temp ( °C )	Humidity
Shower	2			
Drying	15	130		20
Smoke	60	140		40
Cooking steam		155	140	75
Cooking steam		170	145	75
Steam cook		185	158	90
Shower	25		89	
Drying	15			

The sausages were taken out of the smoking room and weighed, put into the cooler overnight and weighed again. The sausages were vacuum packed and stored in the cooler. Treatment 1 was 100% salt sausages treatment 2 was 75% salt and a quantity of whey permeate calculated to be equivalent to 25% of the salty taste of the full salt recipe. Treatment 3 contained 50% salt and 50% WP while treatment 4 consisted of 25% salt and 75% WP (Table 3). The salt contents of each treatment were reduced by 26.25 g because the 28 g sodium nitrite added into the 30 lbs meat had equal sodium. For example, Treatment 2 should have 202.5 g of salt which is 75% of 270 (243.75 g NaCl + 26.25 g NaNO<sub>2</sub>) g of salt added in Treatment 1 (control), but 26.25 g was from sodium nitrite. The other 25% of the control treatment's salt is 67.5 g; this value was multiplied by 12 to get the WP content as 810 g.

*Table 3. Formulation of Each Treatment in the Smoked Sausages*

	Treat 1 100% Salt	Treat 2 75% Salt 25%WP	Treat 3 50% Salt 50%WP	Treat 4 25% Salt 75%WP
Groud pork	13620 g	13620 g	13620 g	13620 g
Biofisol 512	67.5 g	67.5 g	67.5 g	67.5 g
Salt	243.75 g	176.25 g	108.75 g	67.5 g
WP	0 g	810 g	1620 g	2430 g
DI-Water	1350 g	1350 g	1350 g	1350 g
L-Ascorbic acid	3 g	3 g	3 g	3 g
Sodium Nitrate	28 g	28 g	28 g	28 g
Spice	90 g	90 g	90 g	90 g

### 12.3 Water Loss Analysis

The sausages were weighed before cooking and again after cooking and cooling. The water holding capability of the four treatments were measured by the following equation:

$$\text{Water Loss Capability} = \frac{\text{Cooked Weight} - \text{Uncooked Weight}}{\text{Uncooked Weight}} * 100\%$$

(Equation 1)

### 12.4 Physical Property Analysis

For each sausage sample, the pH was measured by Accumet excel pH meter Model XL 15 (Fisher Scientific Inc., Raleigh, NC). Water activity was measured using the AQUA lab model series 3 (Decagon Devices Inc., Pullman, WA). The strength, Cauchy strain, and Hencky strain were measured by Instron model 5565 with static load cell  $\pm 5\text{kN}$  No.50096 (Instron, Norwood, MA).

$$\text{Cauchy strain } \varepsilon_c = \frac{\delta L}{L_0} = \frac{L-L_0}{L_0}$$

$$\text{Hencky strain } \varepsilon_h = \ln(L/L_0)$$

L= Initial Height of sausages (mm);  
L<sub>0</sub>= Extension (mm).

(Equation 2) (Mohos, 2010)

## 12.5 Mineral Analysis

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

## 12.6 Preliminary Sausage Trials

A small trained panel (12 people) consisting of laboratory colleagues and friends was used to do preliminary tasting on the smoked sausages to find the appropriate saltiness for consumer trials. The panelists were given 10 varied salt concentration solutions from 0.2% to 2% which represented as 1 to 10 on the numerical category scale and also 2% WP, 1% GY I, 1% GY IV solution. Each panelist rated the samples of saltiness intensity with numerical category scaling (NCS). Previous research by Dixon (2008) showed that equivalent salty taste for 13.3 g for permeate powder and 1 g NaCl in solution. This trained sensory panel found salty taste for 12.0 g Agri-mark permeate, 5.8 g Green yeast I and 6.8 g Green yeast IV powder equal to 1 g NaCl in solutions respectively. Therefore, the calculation for the amount of Agri-mark WP, GY I and GY IV powder to add to the sausage was found:

9 g NaCl per pound of sausage\* 12.0 g Agri permeate powder per g of NaCl = 108  
grams permeate per pound of sausage

9 g NaCl per pound of sausage\* 5.8 g Green yeast I powder per g of NaCl = 52.2  
grams Green yeast I powder per pound of sausage

9 g NaCl per pound of sausage\* 6.8 g Green yeast IV powder per g of NaCl = 61.2  
grams Green yeast IV powder per pound of sausage

(Equation 3)

Then each panelist was given samples with varying concentrations of salt and WP, GY I and GY IV powder: 100% salt (control); 100% WP; 25% salt 75% WP; 50% salt 50% WP; 75% salt 25% WP; 100% GY I; 25% salt 75% GY I; 50% salt 50% GY I; 75% salt 25% GY I; 100% GY IV; 25% salt 75% GY IV; 50% salt 50% GY IV; 75% salt 25% GY IV. The contents of NaCl were added according to the recipe, and also Agri-mark permeate, GY I, and GY IV powder with equal salt taste to the control treatment's salt. Each panelist rated the samples with a 9-point hedonic scale on overall liking (1 being extremely dislike or absence of attribute and 9 as extreme liking or very high intensity of the attribute) and JAR on saltiness taste (Rothman and Parker, 2009). They were also asked to describe the tastes of the test samples.

### **12.7 Selection of Whey Permeate**

Following the mineral analysis and the small sensory panel of the Agri-mark WP, GY I, and GY IV sausage samples, the Agri-mark WP was selected for additional application in the sausage due to its excellent mineral composition and sensory properties. The salt added to a full salt recipe (denoted as 100% salt) within each sausage recipe was

set at 9 grams of salt per pound (454 g) of smoked sausages. In order to compare the saltiness of the sausages containing salt and WP as a salt substitute for partial replacement of salt, formulations with 100% WP; 25% salt 75% WP; 50% salt 50% WP; 75% salt 25% WP were also prepared for each recipe.

## **12.8 Consumer Acceptance panel**

### **12.8.1 Sample Preparation**

Four sets of 150 cups and lids were labeled with three random digit codes – each set of cups was used for one sausage sample. All samples were prepared with filtered DI water to avoid differences in mineral levels. The different formulations for each sample are indicated in Table 1. Sausages were made one week in advance and kept under frozen conditions (-20 °C).

Three hours before each session, the pre-cooked sausages were removed from the freezer and thawed at room temperature. One hour before each session, sausages were baked at 177 °C (350 °F) in the oven for 15 min. After removing from the oven, samples were placed directly into aluminum sleeves and kept in a warmer of 71 °C until needed.

Sausages were presented in 20-mL plastic cups with a random 3-digit code. As needed, samples were taken directly from the warmer, cut into small pieces (about 10 g each piece), filled 2-3 pieces into each cup and allowed to equilibrate with the lid on, then given to the consumer. Sausages were held in the warmer for less than 30 minutes, which was found to be an adequate hold time to maintain sausage temperature at or above 60 °C. For each sample, fourteen sausages were prepared at 30-min intervals in order to

accommodate twelve panelists. This allowed for a total of eighteen extra sausages available to be given to the panelists as part of the compensation for the panel.

### **12.8.2 Consumer Survey**

Four kinds of smoked pork sausage (100% salt; 75% salt, 25%WP; 50% salt, 50%WP; 25% salt,75% WP) were assessed on 7 consumer liking attributes: overall liking, flavor, saltiness, sweetness, texture, firmness, and juiciness. The objectives were to compare sensory attributes of the partly whey permeate sausage with the regular salt sausage.

The consumer panel filled out paper ballots to assess consumer demographic information as well as reasons behind purchasing of smoked sausages, brand preferences, and purchasing patterns. The panelists consisted of faculty, staff, and students from NCSU, as well as members of the surrounding community. Recruiting was done via email and fliers posted around campus. As compensation for their time, each panelist received some snacks. At the beginning of the panel, all panelists agreed to participate by providing informed consent forms. The questionnaire and ballots were approved by the NCSU Institutional Review Board. Research protocols were approved by the Sensory Services Lab. All tests were performed in a specialized sensory laboratory.

Consumers were asked for their age category, whether they were the primary household shopper, frequency of purchasing sausages, reasons for purchasing sausages, etc. The sensory test for each treatment sausage was completed by 100 panelists. Each panelist answered on the ballots questions about the sausages. To prevent carry-over from

previous samples, the panelists were supplied with distilled water and unsalted Saltine® crackers to cleanse their palates. All tests were performed in a specialized sensory laboratory as individual sessions. The four samples were presented to each panelist in random order. Each sample was evaluated on eight attributes: overall appearance, overall liking, flavor, texture, salty taste, sweet taste, firmness, and juiciness. Each attribute was ranked on a 9-point hedonic liking scale, with 1 corresponding to “extremely dislike or absence of attribute” and 9 corresponding to “extremely like or very high intensity of the attribute”. Each sample was also evaluated using the Just About Right (JAR) scale to determine the perceived saltiness, sweetness, firmness, and juiciness.

### **12.9 Statistical Analysis**

Statistical analysis was conducted by SAS (Version 9.1, Cary, N.C., USA.) and XLSTAT (Version 2010, Paris, France). ANOVA (PROC GLM) was used for analysis of variance of descriptive and consumer data; for each of them, the attribute mean intensities and the degrees of liking were compared, respectively. Frequencies were tabulated for consumer data. Penalty analysis was conducted to identify which product attributes negatively impacted the flavor liking, texture liking and overall liking scores, respectively.

### **12.10 Fat Extraction**

The fat was extracted by the AOAC manual and Soxhlet Extraction methods (AOAC INTERNATIONAL, 2006). Three grams of sample were weighed and blended

into a paste and placed in pre-weighed drying pans. The sample was distributed evenly on the bottom of the pan. The material was dried and cooled in a desiccator.

Several pre-weighed boiling chips were added to the round bottom flasks. The thimble with the samples and glass wool was weighed and about 150 to 200 mL of petroleum ether was added to the 250-mL round bottom flask with a ground glass joint that was then connected to solvent extractors. Thimbles containing sample were placed in solvent extractors. Extractors were connected to condensers and water for condensers and hot plates were turned on. The mixture was brought to a light boil and extracted 6 to 8 hours or overnight. The hot plate was turned off and the samples were allowed to cool. The cooling water was turned off and the thimbles were removed carefully from the condenser and allowed to dry under the hood. The solvent was moved from the condenser into the round bottom flask, and the ether was boiled off under the hood until only fat/oil was left in the flasks, which were placed in desiccators to cool. Cooled flasks and dried thimbles were weighed.

$$\text{Fat content of sample} = \text{weight of (flask + fat)} - \text{weight of flask}$$

(Equation 4)

To calculate percent fat, the weight obtained above was divided by the weight of the sample loaded into the thimble, so the amount of weight lost = the amount of fat extracted.

### **12.11 Calorie Analysis**

Protein contents were calculated from the nitrogen analysis results of the smoked sausages. The average nitrogen (N) content of meat proteins is 16 percent, which led to use of the calculation  $N \times 6.25$  ( $1/0.16 = 6.25$ ) to convert nitrogen content into protein content (Merrill and Watt, 1973). Fat content was determined by the AOAC manual and Soxhlet Extraction methods. The moisture and ash contents were analyzed previously, the the carbohydrate contents were by difference between all other measured components and the total weight. Finally, calories were calculated by the following equation:

The calories of sample= weight of fat \* 9 kcal/g+ weight of protein \* 4 kcal/g + weight  
of carbohydrate \* 4 kcal/g

(Equation 5)

### **12.12 Economic Analysis**

The Economic analysis was performed using Microsoft Excel (Version 2003, United States). Based on the Formulation of each sausage treatment and cost of ingredients.

## **Results**

### **13. Preliminary Data**

The mineral analysis results of WP and GY samples demonstrated that both the GY samples contained more sodium and chloride than the WP. Although the GY samples contained higher levels of calcium, magnesium, potassium, iron, zinc and phosphate, the small panel tests showed that sausage mixtures containing the GY samples tasted very sour and not juicy at all, and had a mushy or friable texture. They also had a pungent alcoholic smell and showed a yellow color. Therefore, the GY salt substitute was not evaluated further in Smoked Sausage Production. In contrast, the small panel test showed that the Agri-mark WP sausage had a fresh dairy flavor and a sweet taste that increased with the amount of added WP. Based upon both the small sensory panel of the Agri-mark WP, GY I, GY IV sausage samples and the mineral analysis results, the Agri-mark WP was selected for additional application in the smoked sausage due to its mineral composition and sensory properties.

#### **13.1 Mineral Analysis of WP and Yeast-Digested Whey Permeate**

Mineral analysis, performed by the ASSL at North Carolina State University, reported that for each permeate, analyses of sodium, chloride, calcium, potassium, magnesium, iron and zinc concentrations were obtained by ICP.

*Table 4. Mineral Content of Whey Permeate and Yeast-digested Whey Permeate (Dry-matter basis)*

	Ash %	P %	Ca %	Mg %	K %	Na mg/kg	Fe mg/kg	Zn mg/kg	Cl %
GY I	32	5.43	2.57	0.52	6.78	24139	634.12	312.54	3.28
GY IV	26	4.79	1.78	0.35	4.20	34826	614.68	303.34	1.69
WP	10.4	-	0.78	0.18	3.13	11400	0.55	1.73	---

Table 4 shows mineral analytical data for whey permeate (WP) and Yeast-Digested Whey Permeate (GY) salt-substitute ingredients to be tested within the sausages. The whey permeate used in the experiment is a powder produced by Agri-mark Company. The whey permeate samples contained the lowest ash contents. Both GY I and GY IV had approximately 1100 times higher iron and 180 times higher zinc levels than the WP. The GY samples had similar amounts of magnesium, calcium, and potassium levels in comparison to WP, when the total ash is taken into account. The sodium level in GY I was twice as high as the WP while GY IV has 3-fold more sodium content than WP, but the ash component of all were similar in sodium.

### **13.2 Water Loss Analysis of WP and Yeast-Digested Whey Permeate Sausage Patties**

The water loss was measured by calculating the moisture retention in the smoked sausages. Results from the small sausage patty test showed the moisture dropped along with the increasing levels of either WP or GY samples in the sausages. GY IV samples had the lowest water retention, losing up to 22.54% of water after baking. And WP samples kept most of the moisture in the sausage patties. Neither WP nor GY sausages patties had better water retention than the control group, which is 100% salt (Table 5).

*Table 5. Water Loss of Sausage Patties Made with Whey Permeate and Yeast-Digested Whey Permeates*

	CONTROL	WP 25	WP 50	WP 75	WP 100
Water Loss %	6.31	8.60	8.84	8.23	13.08
		GY I 25	GY I 50	GY I 75	GY I 100
		7.95	12.56	14.98	13.77
		GY IV 25	GY IV 50	GY IV 75	GY IV 100
		8.53	13.80	18.23	22.54

However, the production of smoked sausages gave opposite results. The 100% salt (Treatment 1) lost the highest amount of water after cooking while the WP sausages had a increasing water retention as the concentration of WP in the smoked sausages increased (Table 6).

*Table 6. Water Loss of Salt and Whey Permeate-Containing Smoked Sausages*

	Treat 1	Treat 2	Treat 3	Treat 4
Water Loss %	6.42	5.34	4.08	3.59

### **13.3 Mineral Analysis of WP and Yeast-Digested Whey Permeate Sausage**

All samples of the sausages contained a sodium concentration very close to the formulated concentration. The results showed a practical decrease of both sodium and chloride contents as the percentage of WP in the samples increased. The 25%, 50%, 75% and 100% WP-containing sausages had 77.8%, 55.9% , 44.4% and 29.4% as much sodium as the 100% salt sausages respectively. For the WP samples, the sodium content was 2840, 2040, 1620 and 1070 mg per serving size (100 g sample) respectively. And for the chloride level, 22.2%, 43.5%, 54.5% , and 70.3% decreases were achieved in comparison to the 100% salt sausages respectively. Since these two minerals may contribute to hypertension, consumers concerned about hypertension might choose these

products. For the GY I samples, the 25% and 50% salt replacement contained 81.4% and 69.3% as much sodium and 72.0% and 55.5% as much chloride, respectively, as the control treatment. The final GY IV samples formulated for 25% and 50% salt replacement contained 74.3% and 53.6% of the sodium and 78.5%, and 54.3% of the chloride, respectively, compared to the control treatment. The two kinds of GY I sausage lowered sodium slightly less and GY IV formula lowered sodium slightly more than the WP samples did. The 25%, 50%, 75% and 100% WP-containing sausages significantly increased the calcium level to 3.6, 5.7, 8.3, 10.1 times higher than the control treatment. The GY I and GY IV treatments had nearly 2 times higher calcium content than the WP samples formulated to the same level of salt replacement. The phosphate was approximately equal in control and all WP samples. The whey permeate samples had significantly more magnesium and potassium in the samples than did the formulations with salt (Table 7). The iron and zinc contents dropped in the WP samples due to the decrease in protein and increase in lactose that comes from substituting WP for a portion of the meat. But iron and zinc contents were much higher in the GY samples than all other samples because the yeast cells contained high levels of iron and zinc. They also had higher percentages of magnesium and potassium at the same salt replacement level in comparison to WP treatments (Table 7).

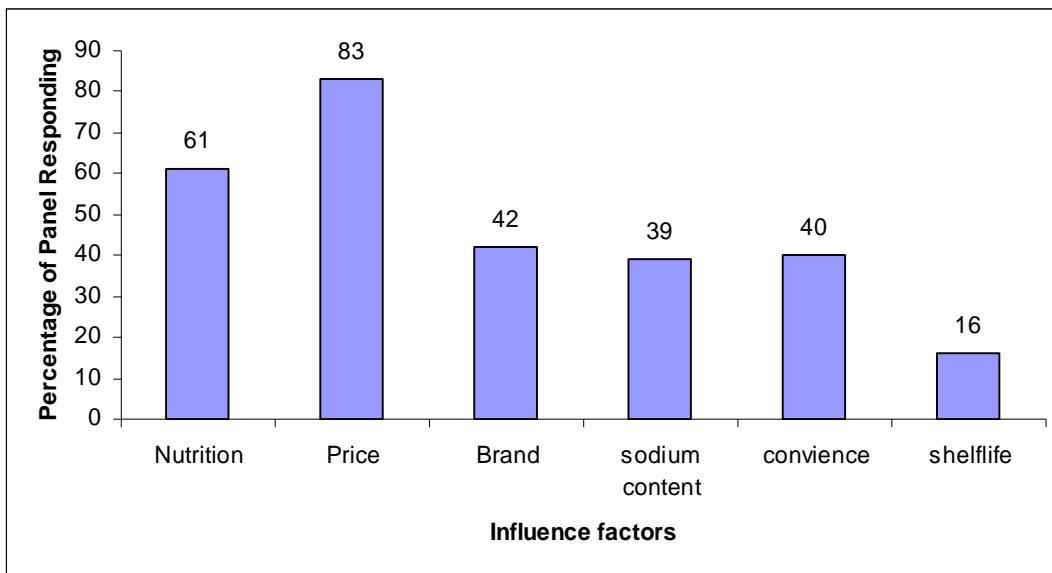
*Table 7. Mineral Analyses of Smoked Sausage Patties using Whey Permeates and Yeast-Digested Whey Permeate as Salt substitutes (Dry-matter basis)*

	Dry %	Ash %	P %	Ca %	Mg %	K %	Na mg/kg	Fe mg/kg	Zn mg/kg	Cl %
CONTROL	32.78	2.90	1.17	0.04	0.09	1.43	36483	37.89	96.52	4.18
WP25%	33.49	3.10	1.19	0.14	0.10	1.65	28396	32.13	79.97	3.25
WP50%	35.46	3.62	1.14	0.22	0.10	1.71	20412	31.41	67.43	2.36
WP75%	37.91	4.34	1.17	0.33	0.11	2.00	16202	25.96	68.07	1.90
WP100%	41.67	4.09	1.13	0.40	0.12	2.02	10724	24.34	58.20	1.24
GYI25%	32.26	3.71	1.51	0.22	0.12	1.64	29696	92.49	101.59	3.01
GYI50%	34.15	3.54	1.92	0.44	0.15	1.90	25266	162.90	131.21	2.32
GYIV25%	36.28	3.46	1.38	0.25	0.11	1.71	27113	82.29	112.63	3.28
GYIV50%	37.90	3.72	1.55	0.41	0.14	1.79	19542	117.92	118.17	2.27

### 13.4 Consumer panel Demographics

The consumers (n=100) consisted of 46 men and 54 women. The consumer results showed that women were more concerned with the sodium content of the sausages (46.3%) than the men (30.4%), while men's choice of sausages depends more on the brand (45.7% for men and 38.9% for women). For the consumer survey, 75% of the consumers were between the age of 20 and 29 years old, 7% were between 30 and 39 years old, 6% were between 40 and 49 years old, 9% were between 50 and 59 years old, and 3% were between 60 and 69 years old. The concern for reducing sodium intake increased with age, suggesting older people are more careful to prevent high sodium intake, which may lead to hypertension and other disease. Most of the consumers (87%) were householders, which means they are the primary shopper. From Table 8, householders were more concerned with the sodium contents of the sausages (42.5%) than the non-householders (15.4%) while non-householders were more concerned with convenience (53.85%). Most consumers stated that they consume sausages several times

a month (60%) and 14% eat sausages a few times a week. The householder population was more willing to buy the sodium-reduced sausages than the non-householders (46.0% and 15.4% respectively). The main reason consumers eat sausages was because of price (83%), nutritional value (61%), and the brand (42%) while 39% of consumers will consider sodium content as one of their purchase guides (Figure 1). Among these consumers, 30% were very knowledgeable of the benefit of reducing sodium intake, and 64% of consumers know some of the risks of high sodium intake. Finally, 42% of panelists showed intention to purchase reduced sodium sausages while 47% were unwilling to make this purchase and 11% were undecided. All of these results are shown in Table 8.



*Figure 1. Factors Influencing Purchasing Smoked Sausages*

*Table 8. Consumer Preference Of Smoked Sausages (N=100)*

Gender group	54% female 46% male
Age group	75% 20-29 7% 30-39 6% 40-49 9% 50-59 3% 60-69
Role in purchase	87% primary household shopper 13% non-primary household shopper
Factors considered in purchase*	61% nutrition 83% price 42% brand 39% sodium content 40% convenience 16% shelf life
Knowledge of salt-containing foods and health	30% very knowledgeable 64% some knowledgeable 6% not knowledgeable
Frequency of sausage consumption	14% few times per week 60% few times per month 25% few times per year 1% never
Willing to purchase reduced sodium sausage	42% have willing 47% have no willing 11% not sure

\*indicates consumers were allowed to choose more than 1 category, so percentages do not add up to 100%.

Penalty analysis is a methodology for determining if an attribute is less than optimal (i.e. above or below a JAR level) on an overall liking of the product scale. Penalties are usually analyzed by plotting the mean drops against the percent of respondents for that mean drop. A penalty is usually not computed if the percentage of consumers in the Too Low (TL) or Too Much (TM) categories is less than 20%.

The penalty results revealed that about 23% of consumers indicated the Treatment 1 sausages (100% salt) were too salty and 32% of consumers thought the sausages tasted not sweet enough ( $P < 0.05$ ). All of these decreased the overall liking of Treatment 1 sausages (Figure 2). Both treatment 2 sausages (25% WP, 75% salt) ( $P < 0.05$ ) and treatment 3 sausages (50% WP, 50% salt) were lacking of saltiness ( $P < 0.05$ ) (Figure 3 and Figure 4). For Treatment 4 sausages (75% WP, 25% salt), 60% of consumers indicated the sausages were too low in saltiness and 62% of consumers thought of they were too sweet ( $P < 0.05$ ) (Figure 5). The improvement could be an increase (reacting Too Little) or a decrease (reacting Too Much) in the attribute. Making the indicated improvement would increase the Overall Liking of the product. In general, the Overall Liking of the product will rise as the consumers' sensory subjective evaluation rises to an optimal JAR level.

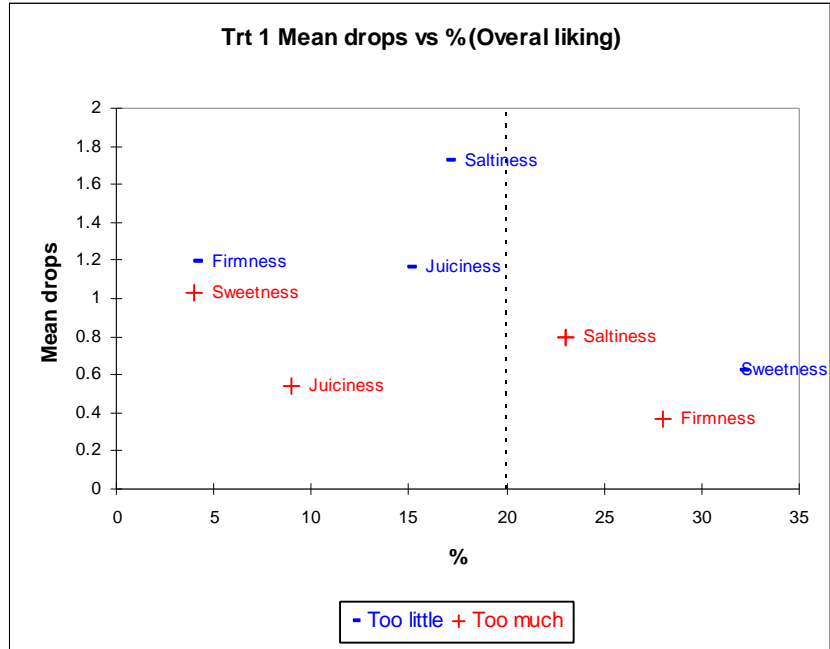


Figure 2. Penalty Analysis of Consumer Liking on Trt 1 Smoked Sausage's Texture and Flavor

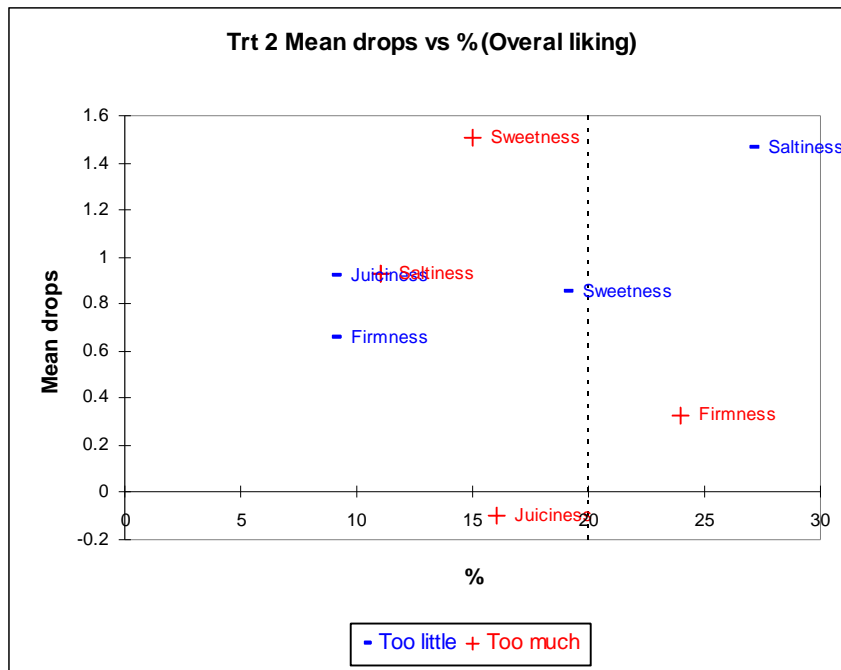


Figure 3. Penalty Analysis of Consumer Liking on Trt 2 Smoked Sausage's Texture and Flavor

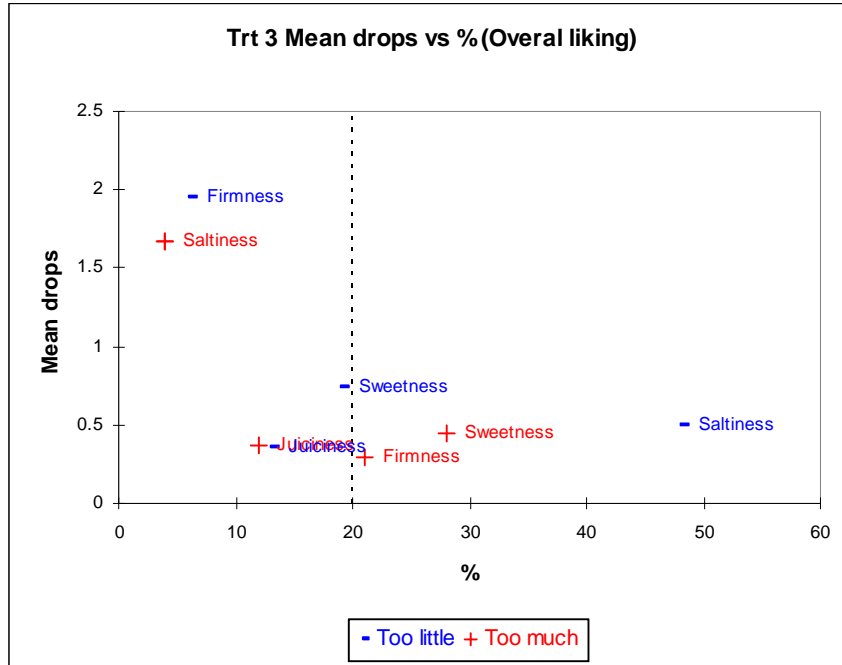


Figure 4. Penalty Analysis of Consumer Liking on Trt 3 Smoked Sausage's Texture and Flavor

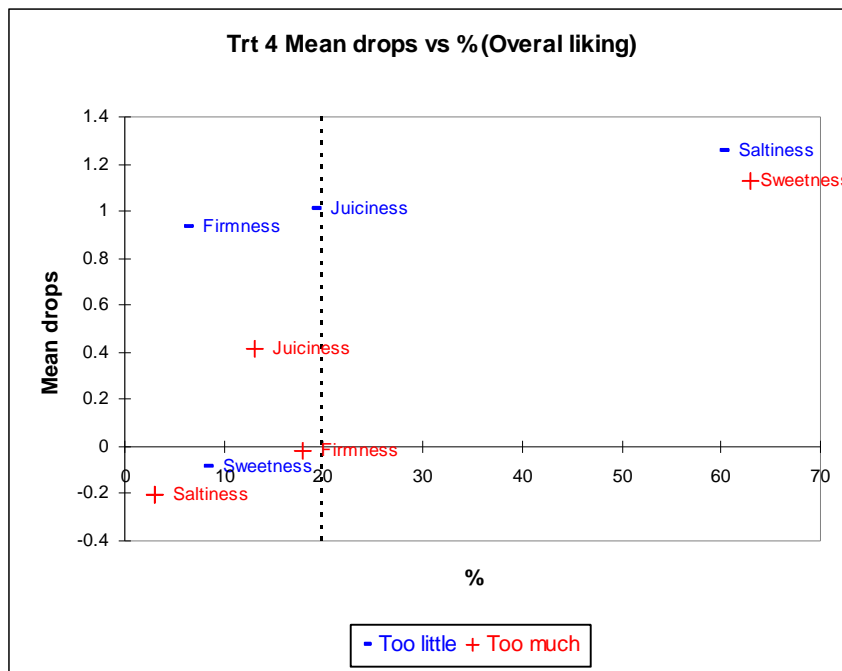


Figure 5. Penalty Analysis of Consumer Liking on Trt 4 Smoked Sausage's Texture and Flavor

### 13.5. Consumer Acceptance Data

The consumer panel consisted of 46 men and 54 women. Most participants were between 20 and 29 years old. On average the participants consumed sausage at least once a month. As the reasons that influence participants' purchasing, price, nutrition and brand were ranked highest. Women were more concerned about the sodium content and nutrition value. More women than men were willing to purchase reduced-sodium sausage, on average. Most women were house-holders and in charge of shopping. Overall liking, overall flavor, overall texture, salty taste intensity, sweet taste intensity, overall firmness, and overall juiciness were ranked on a 9-point hedonic liking scale. Each sample was also evaluated using the Just About Right (JAR) scale to determine the perceived saltiness, sweetness, firmness, and juiciness.

The consumer panel results in Table 9 show there was no significant difference in overall liking between the control sausages (100% salt) and 25% salt-replaced sausages ( $P < 0.05$ ). And there was no significant difference on the flavor-liking intensity among the 100% salt sausages, 25% salt replacement sausages and 50% salt replacement sausages ( $P < 0.05$ ). The participants could not tell the difference for texture or firmness among the four samples. The sausages with 25% replacement with whey permeate got the highest score on flavor liking intensity, and also had the best texture, firmness and juiciness. The 100% salt sample had the highest salty taste intensity at  $5.83 \pm 0.165$  on the 9 point hedonic scale but the 25% salt replacement sample, with a  $5.48 \pm 0.155$  score, was not significantly different from the full salt formulation ( $P < 0.05$ ). The JAR scale scored 100% salt sausages as nearly "just about right" and the other three replacements

were in between “not salty enough” and “just about right” saltiness (Table 10). But there is no significant difference between 100% salt and 25% replacement sausages ( $P < 0.05$ ). The 75% salt replacement sausages showed the highest score on the sweetness intensity. The results were the same as the 9-point Hedonic score (Table 9). From Table 11, 60% and 62% consumers thought the 100% salt and 25% WP replacement sausages had just about right saltiness, but more people thought 25% WP replacement sausages were lacking saltiness. The consumers also showed an increased too sweet judgement along with the increased amounts of WP in the sausages. All the samples showed no significant difference on the juiciness aspect ( $P < 0.05$ ). And for the firmness, only 100% salt and 75% replacement sausages had significant difference ( $P < 0.05$ ) (Table 10, Table 11).

*Table 9. Mean Values of 9-Point Hedonic Scale Consumer Acceptance of Control and WP Sausages*

	Treat1	Treat2	Treat3	Treat4
9-Point Hedonic Scale				
Overall liking	a 6.54	ab 6.52	bc 6.11	c 5.71
Std. Error	0.158	0.145	0.160	0.183
Flavor	a 6.32	a 6.40	a 6.00	b 5.36
Std. Error	0.164	0.136	0.163	0.199
Saltiness	a 5.83	a 5.48	b 4.88	c 4.37
Std. Error	0.165	0.158	0.174	0.193
Sweetness	a 4.56	b 5.12	b 5.28	c 6.42
Std. Error	0.167	0.164	0.179	0.1656
Texture	a 6.20	a 6.35	a 6.16	a 6.28
Std. Error	0.178	0.147	0.162	0.169
Firmness	a 6.27	a 6.41	a 6.22	a 6.30
Std. Error	0.170	0.152	0.172	0.168
Juiciness	ab 6.55	a 6.71	ab 6.42	b 6.16
Std. Error	0.165	0.157	0.164	0.179

1. Attributes were scored on a 9 point hedonic scale where 1=absence of attribute or dislike extremely and 9=very high intensity of the attribute or like extremely.
2. LSD = least significant difference  $p < 0.05$ .
3. Treatment 1 is 100% salt sausages made with 15.25g/kg salt, Treatment 2, Treatment 3, Treatment 4 are sausages made with WP equivalent in salty taste to 25, 50 or 75% of the salt respectively.

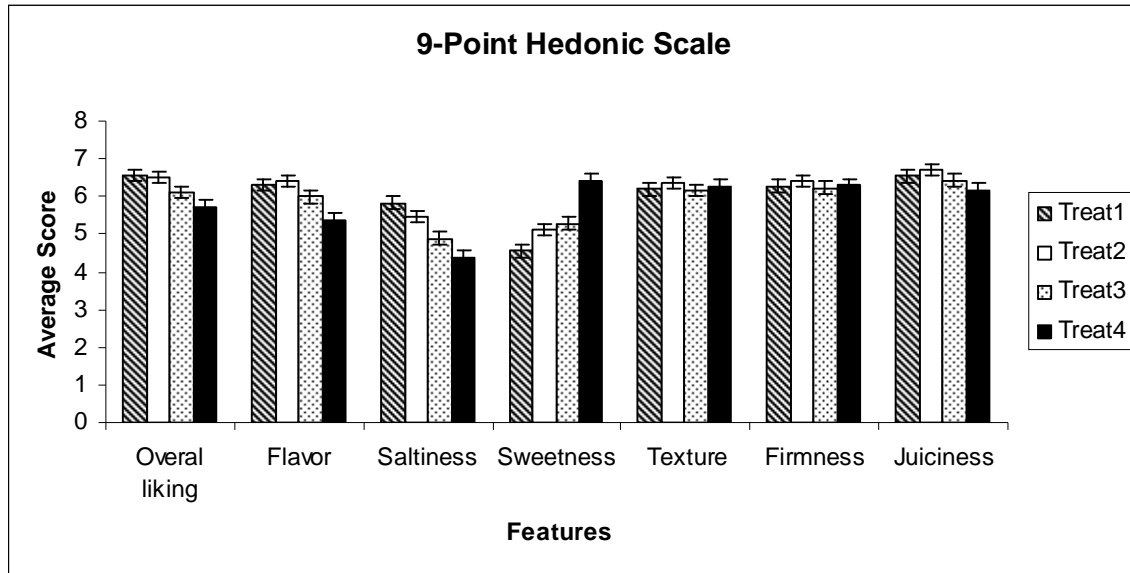


Figure 6. Column table of Mean Values of 9-point Hedonic Consumer Acceptance for Control and WP Sausages

1. Treatment 1=Control-100% salt sausages; Treatment 2= 25% salty-taste replacement sausages; Treatment 3=50% salty-taste replacement sausages; Treatment 4=75% salty-taste replacement sausages

Table 10. Mean Values Of JAR Consumer Acceptance Of Control And WP Sausages

	Treat1	Treat2	Treat3	Treat4
JAR				
Saltiness	a 3.03	a 2.82	b 2.49	c 2.26
Std. Error	0.0703	0.0642	0.0689	0.0774
Sweetness	a 2.63	b 2.89	b 3.04	c 3.67
Std. Error	0.0747	0.0737	0.0828	0.0829
Firmness	a 3.28	ab 3.18	ab 3.17	b 3.14
Std. Error	0.0604	0.0626	0.0551	0.0532
Juiciness	a 2.93	a 3.08	a 3.00	a 2.93
Std. Error	0.0573	0.0580	0.0586	0.0640

1. Attributes were scored on a JAR scale where 1= Not \*\* at all, 2= A little lower than enough \*\*, 3= Just about right, 4= A little higher than enough \*\*, 5= Too much \*\*, \*\* means each attribute.

2. LSD = least significant difference  $p < 0.05$ .

3. Trt 1 is 100% salt sausages made with 15.25g/kg salt, Trt 2, Trt 3, Trt 4 are sausages made with WP equivalent in salty taste to 25, 50 or 75% of the salt respectively

*Table 11. Percentage of Panelists' Responses to the JAR Scale Consumer Acceptance for Control and WP Sausages (N=100)*

Variable	Level	Trt 1 %	Trt 2 %	Trt 3 %	Trt 4 %
Saltiness	Not salty enough	17.00%	27.00%	48.00%	60.00%
	JAR	60.00%	62.00%	48.00%	37.00%
	Too salty	23.00%	11.00%	4.00%	3.00%
Sweetness	Not sweet enough	32.00%	19.00%	19.00%	8.00%
	JAR	64.00%	66.00%	53.00%	29.00%
	Too sweet	4.00%	15.00%	28.00%	63.00%
Firmness	Not firm enough	4.00%	9.00%	6.00%	6.00%
	JAR	68.00%	67.00%	73.00%	76.00%
	Too firm	28.00%	24.00%	21.00%	18.00%
Juiciness	Not juicy enough	15.00%	9.00%	13.00%	19.00%
	JAR	76.00%	75.00%	75.00%	68.00%
	Too juicy	9.00%	16.00%	12.00%	13.00%

Attribute likings were scored on a Just about right (JAR) scale, where 1, 2 = Not \*\* enough, 3= Just about right, 4, 5= Too much \*\*, \*\* means each attribute.

Trt1=Control-100% sausages; Trt2= 25% salty-taste replacement sausages; Trt3=50% salty-taste replacement sausages; Trt4=75% salty-taste replacement sausages

### **13.6. Physical Properties of Whey Permeate Sausages**

The pH and water activity decreased along with the increasing use of WP in the sausages. The water activity ( $a_w$ ) was reduced due to the high lactose in the WP that could bind with water to lower the content of free water molecules. Although salt has the same role as the lactose, it contributes less than the lactose to the water activity reduction; as the ratio of lactose to salt contents in the sausages increases,  $a_w$  decreases. Because water is necessary for microorganisms to grow in food, decreasing water activity could help to preserve food for longer time. Table 12 results showed that pH dropped from 5.91 to 5.26 with the increased WP content in the sausages.

The compression tests showed that all sausages had a good deformability since they did not break under high pressure and could return to their original size quickly. Because Treatment 2 sausages had the biggest cross sectional area, they needed more force to achieve the same extension (Figure 7). There was no significant difference among the Cauchy strain and Hencky strain strength properties ( $P < 0.05$ ). All sausages displayed great texture properties (Table 12).

Table 12. Physical Property of Whey Permeate and Control Sausages

	pH	aw	Height (mm)	Diameter (mm)	Break (N)	Extension (mm)	Cauchy strain $\epsilon_c$	Hencky strain $\epsilon_h$
Treat1	5.91	0.975	33.9	24.3	37.0	9.9	0.71	-0.89
Treat2	5.70	0.973	33.9	32.1	52.9	10.0	0.71	-1.17
Treat3	5.33	0.967	33.9	30.6	40.6	10.0	0.71	-1.12
Treat4	5.26	0.966	33.9	31.2	40.9	10.0	0.70	-1.14

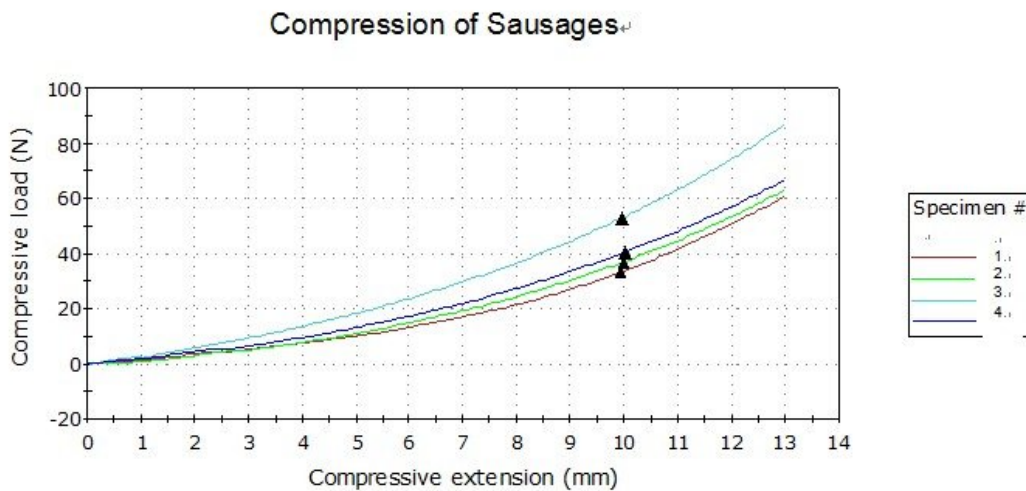


Figure 7. Compression Test of the Whey Permeate and Control Sausages

#### 14. Calorie Analysis

According to the Table 13, Treatment 1 (100% salt) contained 14.52% protein, 2.79% carbohydrate and 22.77% fat; treatment 2 (75% salt, 25% WP) contained 14.40% protein, 9.42% carbohydrate and 19.70% fat; treatment 3 (50% salt, 50% WP) contained 13.24% protein, 10.69% carbohydrate and 19.05% fat; treatment 4 (25% salt, 75% WP) contained 13.28% protein, 14.89% carbohydrate and 16.01% fat. According to standard formulas that 1 gram carbohydrate or protein has 4 calories and 1 gram fat has 9 calories (NutriStrategy, 2010), the calories of each of the sausage treatments 1-4 were 274.1, 272.6, 267.2, and 256.8 calories per serving (100 g), respectively.

Table 13. Analyses of Nutrients in the Smoked Sausages

Trt	Dry	Ash	Moisture	Fat	Protein	Carbohydrate	Calories ( per 100 g )
1	42.98%	2.90%	57.02%	22.77%	14.52%	2.79%	274.2
2	46.62%	3.10%	53.38%	19.70%	14.40%	9.42%	272.6
3	46.60%	3.62%	53.40%	19.05%	13.24%	10.69%	267.2
4	48.53%	4.34%	51.47%	16.01%	13.28%	14.89%	256.8

#### 15. Microbial Growth in Sausage Products and Shelf-Life

Although there was a decrease of the water activity and pH results with the increasing use of WP in the sausages, they were still not low enough in water activity to prevent most microorganisms' growth. Most bacteria associated with food-borne illness cannot grow in conditions that have water activity lower than 0.91 and pH lower than 4.6 (low acid food) (FDA, 2010). So the sausages needed additional methods to inhibit spoilage. The sodium nitrite added in the sausages helped to inhibit *Clostridium botulinum* and *Clostridium perfringens* growth. These two kinds of bacteria can produce

extremely toxic materials that can kill an adult at an incredibly low dose ( $10^{-8}$  g) (Moeller et al., 2003). In addition to the sodium nitrite, the heating process also helps to preserve food. The toxins produced by *Clostridium botulinum* and *Clostridium perfringens* are not heat-stable, so will break down into benign material during thermal processing. Thermal processing can eliminate the *Salmonella spp.* and *Listeria monocytogenes* because the sausages are heated to 71 °C (160 °F) in manufacturing and 157 °C (315 °F) before eating. Although the sausages were pre-cooked, they still needed to be vacuum packaged and stored frozen. The shelf life could be up to 1-2 months if the sausages are frozen or 2 weeks in the refrigerator (USDA, 2009). The sodium chloride in this research's sausages was partially replaced by whey permeates, which contains a high amount of potassium chloride and other salts. There should be no significant difference on the microbial growth between the salt sausages and WP sausages when they were stored under the same conditions. Research conducted by Desmond (2006) demonstrated that when sodium chloride is replaced by either potassium chloride or magnesium chloride in meat products, there are no significant differences in microbial growth (Desmond, 2006). An experiment designed by Gelabert that observed the growth of *Listeria monocytogenes*, *Clostridium*, *Staphylococcus aureus*, *Micrococcaceae*, Lactic acid bacteria, and aerobic mesophylic total count in sausages by salt substitutes showed that except for slightly higher counts of *Micrococcaceae* in the potassium chloride salt substitute treatment, there were no significant differences in bacterial count between the control sausages and the potassium chloride containing sausages for all other bacteria (Gelabert et al., 2002).

## 16. Economic Analysis

The pork wholesale value is \$1.45/lb (ERS/USDA, Oct, 2010). The whey permeate is \$0.75/lb (Agri-mark Company, Lawrence, MA, Nov, 2010). The salt is \$0.50/lb (Walmart, Raleigh, NC, Nov, 2010). The smoked sausage is sold at \$17.95/lb, according to information provided by the The Frenchy Bee Company, Woodinville, WA (Nov., 2010). The cost of whey permeate is mainly contributed by the transport and drying costs, because whey permeate is the by-product of making cheese and whey protein concentrate.

We established a model using 1 lb of sausages for the cost analysis. We assigned all other materials added in the meat a cost of “0” because they are all added at small amounts and at the same level. Then, in consideration of loss during the processing, for each pound (454 g) of sausages, the 100% salt sausages used 429.1 g meat and 7.2 g salt; the 25% salt-replaced sausages contain 402.9 g meat, 5.2 g salt and 23.9 g WP; the 50% salt-replaced sausages contained 381.7 g meat, 3.0 g salt and 45.4 g WP; the 75% salt-replaced sausages contain 369.5 g meat, 1.1 g salt and 64.9 g WP. The materials cost of each sausage is \$1.38, \$1.33, \$1.30, and \$1.29 per pound, respectively. From the results, we can see the 75% salt replaced sausage has the lowest cost which also means it can give the manufacturers more profits. And the cost dropped with the increasing WP content in the sausages.

## **Discussion and Conclusions**

Whey permeate from ultrafiltration of whey and milk is considered a low-price by-product material. With increasing cheese and whey protein concentrate production there will be more and more whey permeate available. Whey permeates can provide various minerals which contribute to a salty taste even if the sodium content is low. This property is desired by the industry since it can be a good candidate for a salt substitute. Salt substitutes are widely used especially by the hypertensive populations, because dietary salt is considered as a major contributing factor.

Hypertension is prevalent in modern society. According to recent estimates, the worldwide prevalence of hypertension in 2000 was 26%, totaling 1 billion people and will increase to 29% by 2025 (Kearney et al., 2005). Sodium and chloride are very high in certain foods. Salt added during food processing and salt added at the table or in cooking contribute to the high salt diets because salt is added to foods as a preserving agent and also used to provide flavor and texture. High amounts of salt intake can result in increasing body water weight, extracellular fluid volume, plasma volume and total exchangeable sodium, which all contribute to hypertension. An analysis of the top 20 sodium-contributing foods consumed by Americans showed that only three of these foods are meat or meat-containing products (NHANES, 2003-2004). Product introduction data showed that sodium-reduced foods would be a key trend (Malherbe, 2003). Across the board, there has been an increase in the number of new low-salt products on the market. According to Mintel's Global New Products Database (GNPD), there were 428 such

launches in the U.S. in 2006, 542 in 2007, and 533 in 2008. So there is an urgent demand to find a salt substitute to lower sodium and chloride in meat products.

Water Loss was measured by calculating the moisture retention in the smoked sausages. The small smoked sausage patty test using baking in a dry oven showed that the moisture dropped along with the increasing levels of WP or GY samples in the sausages. But the pilot plant production in a smoke house demonstrated opposite effects in that the WP incorporated in the smoked sausages helped to keep moisture. This difference may be due to the varied processing times, temperatures and procedure steps. Since the WP sausages had more lactose content that could bind with free water in the sausages, it should help to increase moisture retention and make the sausages taste juicy. Water in the sausages can improve the consistency of the mixture and to dissolve solid ingredients. Results of small sausage patty test may have been caused by insufficient processing time, higher temperature, no-casing protection and different humidity procedures.

Mineral analysis of raw whey permeate (WP) and yeast digested whey permeates (GY) showed that the GY samples contained higher levels of calcium, magnesium, potassium, iron, zinc and phosphate than the WP. Both GY I and GY IV had a higher saltiness intensity than WP samples. But GY samples had more sodium and chloride contents and a pungent alcoholic smell. Results of small panel testing showed the GY-containing sausage patties tasted sour and not juicy. In contrast, the raw WP samples had a fresh dairy flavor and sweet taste. The DASH diet recommends increased intake of

potassium, calcium, magnesium and other minerals by promoting a higher intake of fruits and vegetables (Champagne, 2006). WP can do the same things with its high contents of all minerals listed. Finally, Agri-Mark whey permeate was chosen for the permeate to be used as the salt substitution in the smoked sausages.

In the consumer acceptance trials, sausages made with 25% WP replacement of salt taste were found not significantly different from the 100% salt sausage for most sensory properties both on the 9-point hedonic and JAR scales ( $P < 0.05$ ). Most people could not tell the difference between these two kinds of sausages and they liked the sweet taste in the 25% WP-containing sausages. The consumer panel results in Table 7 show there was no significant difference in overall liking between the control sausages (100% salt) and 25% salt-replaced sausages ( $P < 0.05$ ). Similar results occurred for the intensity of the salty taste of soups (Dixon, 2008). For the saltiness intensity, the JAR scale scored 100% salt sausages as nearly “just about right” and the other three replacements were in between “not salty enough” and “just about right”. These were all somewhat in lack of saltiness. Sweetness score increased with more incorporation of WP into the sausages because the high level of lactose in the WP. There was no significant difference on the flavor liking intensity among the 100% salt sausages, 25% salt replacement sausages and 50% salt replacement sausages ( $P < 0.05$ ). Also, the participants could not tell the difference between texture and firmness among the four samples. And in JAR results, all the samples showed no significant difference on the juiciness aspect ( $P < 0.05$ ). For the firmness, only 100% salt and 75% WP replacement sausages were significantly different

( $P > 0.05$ ). Among all four kinds of sausages, the 25% WP-containing sausages not only got the highest score on flavor liking intensity, but also had the best texture, firmness and juiciness. In a word, there was no significant difference between 100% salt and 25% WP-containing sausages ( $P < 0.05$ ). So the 25% WP-containing sausages could be considered a successful product in matching of sensory properties, but it would take somewhat higher WP replacement to achieve the 25% sodium reduction needed to label the sausages as reduced sodium.

In the consumer panel, most women were the house-holders since they were the primary shoppers of the family. So women were more concerned with sodium-reduction and nutritional value because they want to keep the whole family healthy. More women than men were willing to purchase reduced-sodium sausage on average. Older people were also more willing to purchase reduced sodium sausages. Price, nutrition and brand were the three top reasons that influenced participants' purchasing. Sodium content was not a primary concern but still some people made it as a reference while purchasing sausages. The data showed that 30.4% of the men and 46.3% of women marked sodium as a concern for purchasing smoked sausages. Since too much lactose reduced the flavor intensity of the salt and flavorings in the higher concentration WP sausages, many of the participants stated their reason as lack of saltiness, too sweet, or they did not care about the high sodium intake for the smoked sausages. The penalty results demonstrated that some consumers thought Treatment 2 sausages (25% WP, 75% salt) didn't taste salty enough. For Treatment 3 sausages (50% WP, 50% salt), consumers thought these

sausages appeared to have a little greater firmness, a little too much sweetness, and not enough saltiness relative to expectations. More than half of consumers indicated the treatment 4 sausages (50% WP, 50% salt) were lacking of saltiness and too sweet. Improvements should be made to increase (reacting Too Little) or a decrease (reacting Too Much) in the attribute to raise the consumers' sensory subjective evaluation to an optimal JAR level.

From the mineral analysis results, the sodium content of 0%, 25%, 50%, 75%, 100% WP versions of the samples was 1370, 1090, 840, 720 and 520 mg per serving size (100 g sample) respectively. Compared to the control (100% salt) sausages, they reduced sodium levels by 20.4%, 38.7%, 47.4% and 62.0%. Chloride content was proportional to the amount of salt added to each treatment, as expected. According to FDA labeling laws, a “reduced-sodium” product must feature a 25 percent reduction of sodium from the original formulation (Stehlin, 1993). This goal could be met by salt replacement with a formulation intermediate to treatment 2 and treatment 3 sausages, probably about 35%. And some people liked the WP sausages better for flavor, juiciness, firmness, and saltiness aspects while reducing sodium contents in the sausages. Now there are no rules on the “reduced-chloride product” because most people still think the main reason for hypertension is high sodium intake. But some studies suggest that the chloride might induce hypertension rather than sodium. Animal studies comparing multiple forms of sodium with sodium chloride show the real cause may be chloride because blood pressure tended to fall with the reduction of sodium chloride and not with other forms of sodium

from the diet, such as sodium citrate, or sodium phosphate (Kurtz et al.,1987). However, because most of the dietary chloride that is absorbed accompanies dietary sodium absorption, chloride is regulated indirectly through sodium intake. This study suggests there is an effective way to reduce sodium and chloride in the sausages with WP as a salt substitute or at least a partial substitution. Using a potassium chloride salt substitute would not reduce chloride to this extent. The findings of this research may benefit hypertensive populations by offering food processors a better choice of salt substitutes (Karanja, 2007).

Caloric analysis indicated that the smoked sausages in Treatments 1-4 had about 274.1, 272.6, 267.2, and 256.8 kcal per serving (100 g) respectively. As more WP was incorporated into the sausages, more carbohydrate and slightly less fat and protein were present. This was primarily caused by the high lactose contents in the WP. Lactose is the best sugar for infants because it not only helps to develop the nervous system but also facilitates the growth of lactic acid bacteria in the guts. The lactic acid bacteria can digest lactose and form lactic acid which regulates and protects the infant GI tract (DGN, 2010). These organic acids inhibit harmful bacteria growth in the low pH environment and stimulate the peristalsis of the gut. Besides, it provides energy and improves the absorption of calcium for the babies (DGN, 2010). The galactose is important for brain development of children; it can promote the production of cerebrosides and mucopolysaccharides. Lack of lactose may lead to the pedatrophny, acratia, weight loss, and inhibited growth in children (DGN, 2010). Thus, lactose maybe a beneficial food

addition for certain population. The water activity and pH also declined with the higher levels of lactose because some of the lactose decomposed into lactic acid, the whey permeate is acid and the lactose binds with the free water. Lactose also gave WP sausages good texture because the lactose and minerals helped the protein-binding process. Therefore, WP smoked sausages not only supply similar amount of energy to human bodies as the normal smoked sausages but also have the lactose and minerals essential for the growth.

However, three problems still exist in the application of WP in smoked sausages. First, if high levels of WP were incorporated into the sausages, they taste too sweet. Most people didn't accept this taste, but some really like it. The high sweetness intensity also covers a bit of the saltiness that is contributed by the whey permeate. Second, if we heat the sausages to 100 °C (212 °F), the lactose in the sausage from the whey permeate will caramelize and form a brown or black color on the surface of the sausages. Because most people usually set their ovens at 315-450 °C to bake sausages, the lactose is heated out of its range, decomposes and forms lactic acid and some formic acid and causes the pH of the sausages to decrease. Whittier and Benton had shown that the hydrogen-ion concentration increases at a rate that is a function of the lactose concentration and the time and temperature of heating (Whittier and Benton, 1925). These chemical reactions not only give a sour flavor to the sausages but also lower the nutritional value. Third, lactose-intolerance people cannot consume the whey permeate products. This population cannot eat dairy food because they are unable to digest the lactose in the milk. In their

digestive system, they lack the enzyme lactase that breaks down lactose into glucose and galactose so it can be absorbed in the body and burned for energy.

Recent research indicated that all the efforts in the United States over the past 3 decades have had no effect on the population's sodium intake. The failure of the government's efforts has been typically attributed to the food industry's excessive use of sodium in their products. Sodium intake has not increased as processed foods have become saltier because salt is considered as the oldest and most common seasoning and preservative. And another possible explanation is that human sodium intake is a parameter that even the most well-intentioned public policy cannot modify in most people. Current federal dietary guidelines for salt consumption advise that adults should consume no more than 2,300 mg, but some scientists anticipated that the 2010 U.S. Dietary Guidelines are expected to set the safe upper limit for all individuals, regardless of health status, at 1,500 mg. That is less than 40 percent of the average intake (McCarron, et al., 2010). In an effort to obtain a long-term picture of sodium intake in the United States, more sodium-reduced food should be developed and be available in the market for consumer purchasing. The government should explain the benefits of these policies for the food industry and companies to stimulate the development of sodium-reduced food.

Whey permeate is a major whey product that has not been widely used in the food or health industry. For its high level of lactose, mineral contents and low cost, whey permeate could be a new star in food product development. The mineral content of whey

permeate can improve the nutritional quality of foods. Economic analysis showed that WP sausages had lower costs, due to higher production yield. A reality of the food industry is that cost is the most important factor when determining ingredient use. The more functionality a food manufacturer can get for the same cost or equivalent cost, the better. Whey permeate does not contain as much protein as in milk because it is treated with the ultrafiltration process. The whey permeate might be acceptable in the food of milk protein allergy (like casein allergy) patients because permeate contains primarily non-protein nitrogen compounds. In addition to the food applications, the whey permeate is suitable for developing new microorganism culture media because of its high lactose and mineral contents. Whey permeates present a dairy sour and brothy flavor, especially in liquid applications, a problem that will require further research. Further applications for whey permeate range from using whey permeate in sausages as illustrated in this study or developing drugs based on whey permeate culture media. The use of microorganisms to reduce the lactose content of the whey permeate, as is being developed in the Green Yeast products, also holds promise in development of new food ingredients.

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## Appendix

Figure 8. Consumer Acceptance Scoring Ballot

Name \_\_\_\_\_

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

Please choose the one that best describe your feel. Thank you!

Sample # \_\_\_\_\_

1. Overall Liking

Extremely Dislike					Neither Like nor Dislike					Extremely Like
1	2	3	4	5	6	7	8	9		

2. Flavor

Extremely Dislike					Neither Like nor Dislike					Extremely Like
1	2	3	4	5	6	7	8	9		

3. Saltiness

Not salty										Too Salty
1	2	3	4	5	6	7	8	9		

4. Sweetness

Not sweet										Too Sweet
1	2	3	4	5	6	7	8	9		

5. Texture

Extremely Dislike					Neither Like nor Dislike					Extremely Like
1	2	3	4	5	6	7	8	9		

6. Firmness

Extremely Dislike					Neither Like nor Dislike					Extremely Like
1	2	3	4	5	6	7	8	9		

7. Juicyness

Extremely Dislike					Neither Like nor Dislike					Extremely Like
1	2	3	4	5	6	7	8	9		

8. Saltiness

Not Salty at all	Nearly Salty Enough	Just About Right	More than enough Salty	Too Salty
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9. Sweetness

Not Sweet at all	Nearly Sweet Enough	Just About Right	More than enough Sweet	Too Sweet
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10. Firmness

Not Firm at all	Nearly Firm Enough	Just About Right	More than enough Firm	Too Firm
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11. Juiciness

Not Juicy at all	Nearly Juicy Enough	Just About Right	More than enough Juicy	Too Juicy
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What, if anything, did you like about the sample?

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

Figure 9. Consumer Acceptance Panel Demographic Questions

1. Gender:            Male    Female

2. Age

20-29            30- 39            40-49            50-59            60-69

3. Primary household shopper?        Yes    No

4. What influences your shopping purchases?

*Please circle all that apply:*

Nutrition    Price    Brand    Sodium content    convience    shelf life

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 sausage?

*Please circle one:*

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

Do not consume at all

7. Do you purchase reduced sodium sausage?    Yes    No    Don't know

- If no, why not?

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