Flavor Challenges of Sodium Reduction in Processed Meat Products

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Sensory Perception

Consumers determine the acceptability of food products based on sensory perception. These perceptions include sight, touch, smell, taste, and hearing, and these senses translate into appearance, texture, aroma, and flavor in food products (Meilgaard et al., 1991). Consumers often base their meat-purchasing decisions on appearance (Young, 1996) but usually make repeat purchases based on product flavor and texture. The combination of aroma and taste define the flavor of food products and often drive the consumer acceptability of many products. A meat product that is acceptable to consumers should have a pleasant aroma upon cooking and have the desired flavor (taste and aroma) when eaten. Protein receptors in the nose bind volatile aroma compounds that determine the aroma quality of the product and are responsible for the aroma that is perceived by the consumer (Aparecida et al., 2007). The tongue perceives the taste of the product by binding various compounds to certain protein receptors (taste buds) that impart the following basic tastes: salty, sweet, sour, bitter, and umami that are perceived by the consumer (Meilgaard et al., 1991). Sodium chloride is very important to both the taste and aroma of meat products for 3 main reasons. First of all, the sodium in salt binds to protein receptors and imparts the salty taste that most consumers desire. Second, sodium works synergistically with the food matrix to enhance the desirable sensory characteristics in meat such as savory and meaty flavors. In addition, salt is effective at releasing volatile aroma compounds from the food matrix that improve the aroma quality of the product, because it changes the osmotic pressure and makes the volatile compounds less soluble within the food matrix (Mehinagic, 2007), so that they are more easily released into the atmosphere. The main concern that is associated with reducing sodium in processed meat products is not the salty taste that sodium chloride imparts but the ability of sodium to enhance the desired meat/savory flavors in the product. One explanation for salt's ability to enhance flavor is that it extracts the myofibrillar proteins that bind fat and water and helps to retain more of the fat and water in the product, thus enhancing flavor quality. Reduction of sodium, specifically sodium chloride, is challenging for the food and meat industries due to both flavor and protein functionality issues that result in bland products that are not as juicy or tender and do not have optimal texture (Desmond, 2006). Some companies have created meat-related products that have lower than 400 or 480 mg of sodium per serving. Campbell's Soup, Con Agra Foods, General Mills, Hormel, Kraft, Cargill, and many other companies have made progress in reducing sodium in their products and are continuing to develop new products with reduced sodium (Nachay, 2008). These companies have been very successful, but all of their information is proprietary, and minimal information has been reported in literature pertaining to how to reduce sodium content without negatively impacting product quality. It is important for these companies to continue to supply acceptable products with reduced sodium, but it is also important for enhanced consumer education pertaining to the importance of health and diet and for consumers to incorporate lower-sodium diets into their lifestyle (Nachay, 2008). This is the only way that consumers will be able to adapt their tastes to lower-sodium products if flavor enhancers are not used to enhance the saltiness and sensory perception of the meat product (Desmond, 2006).

Flavor Challenges Linked to Sodium Reduction

Sodium chloride is the primary contributor to total sodium concentration in meat products. In processed meat products, sodium chloride salt contributes approximately 79% of the sodium in a meat product, when 2% salt (finished product basis) is utilized (Breidenstein, 1982). Sodium chloride salt is an important ingredient in marinated and processed meat products because it enhances tenderness, juiciness, and flavor, and it is used in processed meat products to extract proteins to improve water and fat binding. It has been reported that, on average, Americans and Europeans consume roughly 2 to 3 times the recommend-

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ed daily allowance for sodium (Nachay, 2008; Desmond, 2006). In addition, meat products contribute roughly 20% of the sodium intake in both the United States and Europe (Engstrom et al., 1997). This is a major concern for the industry, because the ingestion of too much sodium has been linked to hypertension, a condition that is a risk factor for cardiovascular disease (Nachay, 2008). Sodium chloride is the most important sodium-containing ingredient in meat products, and a portion of it can be replaced with alternative ingredients that reduce the overall sodium content in the product. However, sodium can only be reduced to a threshold level, because a certain amount of salt is essential for acceptable texture/protein functionality and flavor.

Phosphates, traditionally sodium phosphates, are important ingredients in processed meat products because they enhance protein extraction, thus improving water-holding capacity (Pearson and Gillett, 1996a). Sodium makes up a smaller percentage of sodium phosphate when compared with sodium chloride and can legally be added to meat products at levels up to 0.5%. Even though sodium phosphates contribute sodium to meat products, they can decrease the amount of sodium chloride that is needed for protein functionality and therefore reduce the overall sodium content in food products (Jimenez-Colmenero et al., 2001). In addition, potassium phosphates can be used in the place of sodium phosphates, and sodium or potassium phosphates can be further enhanced through agglomeration or spray-drying. It is crucial to use sodium chloride and a source of phosphate for protein functionality and taste, but sodium can be reduced at levels between 30 and 50% without negatively affecting flavor by replacing it with potassium in both salt and phosphates when flavor enhancers and masking agents are utilized (Desmond, 2006). Other sources of sodium in meat products include sodium nitrite, sodium ascorbate or sodium erythorbate, monosodium glutamate (MSG), and hydrolyzed vegetable proteins (Desmond, 2006). Most of these ingredients are important in cured meat products, with the exception of MSG and hydrolyzed vegetable proteins. Sodium nitrite and sodium ascorbate/sodium erythorbate make contributions to the sensory characteristics and cured color development in processed meat products, but MSG is merely a flavor enhancer that can be utilized to increase the perception of salty and savory tastes. However, MSG has been linked to people having headaches, and its incorporation as an ingredient is a concern for the industry.

In processed or marinated meat products, potassium chloride (KCl) can be used as a substitute for sodium chloride and impart desirable protein functionality and textural quality in meat products (Pasin et al., 1989). However, KCl consists of potassium ions that bind to protein receptors on the tongue and impart a bitter or metallic taste (Desmond, 2006; Wade, 2006; Nachay, 2008). In addition, there has been some concern reported in Europe that too much KCl in the diet may lead to health problems and that studies need to be performed to determine the effect that consuming high amounts of potassium has on human health, especially in people with type I diabetes and renal disease (Desmond, 2006). However, other sources state that potassium chloride should be healthy for most consumers, because potassium is important in muscle function and counters the effect that salt has on blood pressure (United States Department of Health and Human Services, 2005). Potassium chloride is the ingredient that is used in most reduced-sodium meat applications, and most companies use proprietary ingredients to mask the aftertaste and enhance the product's saltiness. Most products that are used as salt substitutes consist of sodium chloride, potassium chloride, natural flavors, and taste modifiers (Nachay, 2008). Over the last few years, potassium chloride has increased in use and is no longer a detriment to product quality, because there are ingredients available to block its metallic/bitter taste and enhance the salty and meaty flavors that are desired by consumers. A concern also exists that potassium chloride does not preserve or provide the same safety hurdle as sodium chloride, which could lead to potential problems with shelf-life or product safety (Reddy and Marth, 1991).

Technologies to Replace the Flavoring Effects of Salt

The most common technology that is used to replace salt in food products is to substitute sodium chloride with potassium chloride at levels of 20 to 50%. Potassium chloride is the only ingredient that is capable of providing similar improvements in protein functionality to that of sodium chloride, which is expressed in water and fat binding in processed products. Calcium chloride and magnesium chloride can also be used but do not extract/solubilize myofibrillar proteins as well as potassium chloride or sodium chloride. Potassium chloride replaces the functionality that is imparted by sodium chloride in processed meat products, but it does not impart the desired salty taste or enhance the desirable sensory properties of the product. Instead, it imparts a bitter and/or metallic taste. To produce reduced sodium products with similar aroma and taste profiles to marinated and processed meat products, novel ingredient technology is utilized. Most of this information is proprietary, but some of this information is common knowledge and will be discussed in subsequent sections. According to Desmond (2006), there are 3 major approaches that are utilized to reduce sodium content in muscle food products. These include using salt substitutes with masking agents, using flavor enhancers in combination with sodium chloride, and optimizing the salt so that it provides as much flavor as possible to the meat system. These approaches are the most viable options for reducing sodium, because potassium chloride can provide the desired protein functionality requirements in the meat system, but negatively impacts the flavor of the product. To prevent this negative effect on flavor, other ingredients must be utilized.

Potassium Chloride/Alternative Salt Systems

Over the years, the industry has tried to achieve similar product acceptability to products that are formulated with salt by utilizing alternative salts in conjunction with NaCl. These alternative or flavor enhancers include $MgCl_2$, KCl (FDA, 2003a,b), and $CaCl_2$ (Desmond, 2006). In the late 1980s and early 1990s, researchers replaced 50% of the sodium chloride in processed meat formulations with potassium chloride in many different muscle food systems to maintain the desired texture (Balachandran and Vijayan, 1988; Arganosa and Marriott, 1990; Reddy and Marth, 1991). However, minimal products were placed on the market until after 2000, and the majority of these products were introduced over the last few years. These salt substitutes often include potassium chloride, spices, sodium chloride, natural flavors, and other proprietary ingredients (Nachay, 2008). To mask the bitter and metallic taste of KCl, masking agents or flavor enhancers are generally used in these mixtures. For example, Pansalt is a patented salt replacer that consists of sodium chloride, potassium chloride, magnesium sulfate and L-lysine hydrochloride (Desmond, 2006). The L-lysine hydrochloride masks the undesirable tastes that are imparted by magnesium and potassium and enhances the saltiness perception. Many other salt alternatives are available including KCLean Salt, sub4salt, Morton Lite Salt, *SaltWise*, etc. (Desmond, 2006; Nachay, 2008). Other potential salt substitutes include lysine and succinic acid (Desmond, 2006). These ingredients contribute a salty taste but do not provide the protein functionality or preservation effects that are imparted by sodium chloride.

Flavor Enhancers

Flavor enhancers are utilized to augment the flavor that is naturally present in meat products, and sodium chloride salt is the primary flavor enhancer in meat products. If sodium chloride is removed from the food matrix/formulation, other flavor enhancers must be incorporated into the system to make up for the reduction in flavor. These flavor enhancers include monosodium glutamate, inosine monophosphate, guanosine monosphosphate, autolyzed yeast extract, nucleotides, hydrolyzed vegetable proteins, and other potential ingredients (Pearson and Gillett, 1996b; Desmond, 2006). The mechanism of flavor enhancement is not well understood, but researchers have theorized that these ingredients either increase the ability of protein receptors to interact with flavor compounds in both the nose and mouth, interact with the protein receptor sites to improve the environment for taste receptor stimulation, or may even strengthen the synaptic signal from the receptor site to the brain (Hegenbart, 1994). Even though these mechanisms have not been proven, it is well known that these compounds enhance meat flavor, provide a savory note, and augment the salty taste in meat products. Autolyzed yeast and hydrolyzed vegetable proteins can be used to reduce sodium content in meat products. These ingredients consist of by-products from either yeast autolysis or vegetable protein hydrolysis that include amino acids (including glutamic acid) and enhance the flavor of meat products. Autolyzed yeast also naturally forms inosine monophosphate and guanosine monosphosphate, which masks bitterness and enhances flavor. Other flavor enhancers include lactate derivatives, dipeptides, citrate derivatives, lactose, and dextrose (Desmond, 2006; Nachay, 2008).

Masking agents can be used in reduced-sodium meat products to mask or block the bitter taste that is imparted by potassium chloride (Desmond, 2006). The most well known bitter blocker is adenosine 5′ monophosphate. McGregor (2004) stated that adenosine 5′ monophosphate functions by blocking gustuducin activity in taste receptor cells. Gustuducin is a taste receptor cell that recognizes bitter tastes (Wong et al., 1996). If gustuducin activity is blocked, bitter tastes cannot be perceived.

Alternative Salts

Many different salts are naturally available in the environment. Among the most prevalent is sea salt. Sea salt is a broad term that generally refers to unrefined salt derived directly from the ocean or sea and is not refined to the level of most commercial salts. It contains other traces of minerals including iron, magnesium, calcium, potassium, manganese, zinc, and iodine. Table salt, on the other hand, is the most common salt found in the average kitchen, as well as the industry. Table salt usually comes from salt mines and is refined to the point that minerals are removed until it is pure sodium chloride. The industry continues to develop new products in which they are substituting sea salt for pure sodium chloride. Sea salt has a lower sodium content than refined sodium chloride because of the innate impurity of the unrefined salt. Sea salt is gaining popularity in the industry because it allows for yields that are equivalent to products that are made with traditional salts while lowering sodium levels and maintaining the desired flavor.

Researchers have reported that using salt in a flaked and/or an agglomerated form improves the protein functionality and taste bioavailability of sodium when compared with granular salt (Desmond, 2006). The agglomerate structure gives the salt a sponge-like texture, with an increased surface area that enhances its solubility, ability to extract protein, and flavor development. This salt is more bioavailable, thus able to improve water and fat binding. This increases the ability of the meat system to release volatile compounds into the atmosphere, for the product to retain more fat, and the ability of protein receptors to perceive salt. All of these mechanisms improve flavor, thus allowing for lower concentrations of sodium chloride in the finished product.

Another concern for the industry is food safety in regards to microbial growth. By reducing the sodium level, there may be an adverse effect on shelf-life. Salt has always been the most complete preservative in the industry's quest to extend shelf-life in meat products. Rodrigues et

al. (2005) reported that the use of sea salt on cod products displayed the highest microbial counts when compared with a salt solely of NaCl and a natural salt from northern Europe. It is therefore very important to evaluate the effects of reducing sodium content of different foods and how that will in turn affect the food safety of the product (Reddy and Marth, 1991).

Alternative Technologies

Prerigor meat is commonly utilized in sausage products due to increased protein functionality when compared with postrigor meat. This increase in functionality occurs because myosin and actin are not permanently bound as actomyosin. Use of prerigor meat allows for the use of lower sodium content, because less sodium chloride is needed to extract the myofibrillar proteins. These myofibrillar proteins, in the form of myosin and actin, are more effective at binding water and encapsulating fat, which leads to improved aroma and flavor in the product (Claus and Sorheim, 2006).

Hydrostatic pressure can be used in processed meat products, especially emulsion-type products, to improve protein functionality (MacFarlane et al., 1984). Hydrostatic pressure is also very effective at extending shelf-life by destroying spoilage microorganisms and some pathogenic bacteria (Kalchayanand et al., 1998). Researchers have reported that it allows for reduced sodium chloride at a threshold level of 1.5% in breakfast sausages and frankfurters (Crehan et al., 2000; Troy et al., 2001). In these studies, it was revealed that KCl could be used in hydrostatic pressure-treated samples and that salt could be reduced to 1.5% without negatively affecting sensory properties, including saltiness. Hydrostatic pressure seems to be a viable alternative for reducing sodium content in emulsion-type products due to increased protein functionality. The mechanism for maintaining flavor quality has not been reported in literature but is probably related to the increased protein functionality.

Industrial Approaches

There are many products that are available to the industry that allow for the formulation of reduced-sodium meat products. Some of these ingredients have been incorporated into products at companies such as Campbell's Soup, ConAgra, General Mills, Kraft, Hormel, and many other food companies. Some of the products on the market include KCLean Salt (Wixon), SaltTrim (Wild Flavors), sub-4salt (Jungbunzlauer), SaltWise (Cargill), and Salt Balance, Salt Blend, and Lite Salt (Morton Salt) (Nachay, 2008). All of these mixtures are proprietary in nature, but they may include some of the ingredients previously mentioned in this paper. All of these ingredients make it possible for food product development applications that are designed to reduce sodium in meat products. However, there are 2 important concepts to remember in this quest for sodium reduction. First, salt is an important ingredient in meat and other products and is necessary in processed meat products for acceptable functionality and flavor. Second, careful sensory testing must be performed on reduced-sodium products, because consumers are highly variable in what they deem acceptable (Schilling and Coggins, 2007) and reducing sodium content without maintaining quality will not be lucrative for the industry.

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