

Effects of sodium and salt substitutes on freezing characteristics of potatoes

Erica Cramer

Introduction

Heart disease is the leading cause of death in America (Center for Disease Control). The American Heart Association recommends that all adults try to consume less than 1,500mg of sodium per day. In the interest of meeting consumer demand for lower sodium, food processors have been looking for ways to reduce the sodium content of their products. Research has been done on the effects of sodium reduction in meat and poultry processing (Maurer 1983, Terrell 1983). Sodium chloride is used to reduce microbial growth, improve texture, and enhance the flavor of the foods that it is used in. The best substitute for sodium in these products is potassium (Terrell 1983). Mixes containing both sodium chloride and potassium chloride are also recommended (Maurer 1983).

Frozen foods are convenient and inexpensive for busy consumers on a budget. In addition, freezing can maintain the quality of the food (Singh and Heldman 2009). However, many frozen meals are high in sodium. Sodium is used to increase the shelf life and to enhance the flavor of foods (FOODTECH 2009). In order to provide consumers with inexpensive, convenient, and healthy food options, the sodium content of frozen foods should be reduced.

The challenge in producing a frozen product is making sure that it maintains its quality after it has thawed or been heated. The objective of the freezing process is to manufacture a product with small, uniformly-sized ice crystals. This process will create less damage to the cellular structure of the product, and should have more uniform temperature distribution during microwave heating (Singh and Heldman 2009). There are several variables that will affect the size of the ice crystals in the product, including rate of freezing, product thickness, and solute concentration. The presence of sodium in a product will depress the freezing point of the product and affect the formation of ice crystals. Changing the concentration of sodium, or changing from sodium to potassium, will produce different effects on the frozen product. It is necessary to determine the effects that reduced sodium concentration and increased potassium concentration will have on freezing characteristics and the freezing process in order to create quality reduced-sodium frozen products.

This study was conducted to determine the effects of sodium and salt substitutes on the freezing times and hardness of potatoes. Since sodium and other solutes depress the freezing point of water, it is predicted that higher concentrations of a given solute will decrease the time needed for the potato slice to freeze from the initial freezing point. With a longer freezing time, larger ice crystals will form, cell walls in the potato will be ruptured, and less force will be required to compress the thawed potato slices. Shorter freezing times will also result in more firm potato slices.

Methods

Solutions of salt and salt substitute were prepared. The salt substitute was Morton's Lite Salt, which contains potassium chloride as a partial substitute for sodium. The solutions were prepared to different concentrations. The initial salinity of the solutions was measured. The solutions were placed into containers with 100ml of solution in each container.

Russet potatoes were obtained from a local grocery store (Giant Eagle, Columbus, OH). The potatoes were sliced to 1/4 inch thickness. They were blanched by being placed in boiling water

for 1 minute, then cooling in ice water for 1.5 minutes. The slices were patted dry. One potato slice was placed in each container of solution for over 8 hours.

The slices were removed from the solutions and patted dry. The final salinity of the solutions was measured. Two freezing methods were used, one slow and one quick. For the slow methods, the potato slices were placed between single layers of plastic wrap, then placed in a still freezer until they reached an internal temperature of -18°C . The freezer was set to around -21°C . For the quick method, an ice bath of ethanol and dry ice maintained at -65°C was used to freeze the slices. The temperature was monitored during the freezing process, and the slices were brought to a temperature of -20°C . The time to freeze and the temperatures were recorded. The slices were placed on the middle shelf of a Kenmore Freezer set to the coldest setting for 30 minutes.

The slices were removed from the freezer, and they thawed either at room temperature or in the microwave. The slices that were thawed in the microwave were microwaved for 4 minutes at 10% power.

The texture of the thawed potatoes was tested with a texture profile analyzer (Stable Microsystems). The centers of the potato slices were cut out and compressed to 40% of their original height. The hardness was determined by measuring the initial force required to compress the potato slices.

Results and Discussion

Concentration vs. Characteristic Freezing time

It was predicted that samples that had absorbed a higher concentration of a given salt would take longer to freeze because of the depression in the freezing point. Overall, the samples tended to freeze more quickly as the concentration of solute absorbed by the potatoes increased. The samples that were frozen slowly showed a stronger correlation between concentration and freezing temperature (Figure 1). The samples that were frozen quickly showed a wider variation (Figure 2).

Figure 1. Effect of solute concentration on characteristic freezing times of potatoes in -21°C freezer.

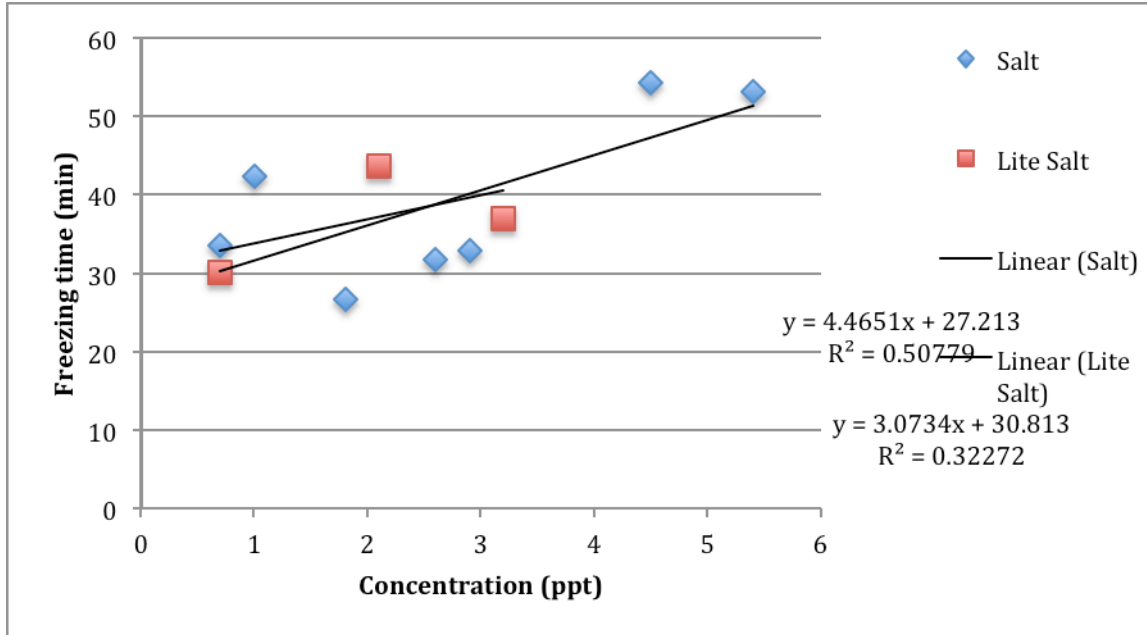
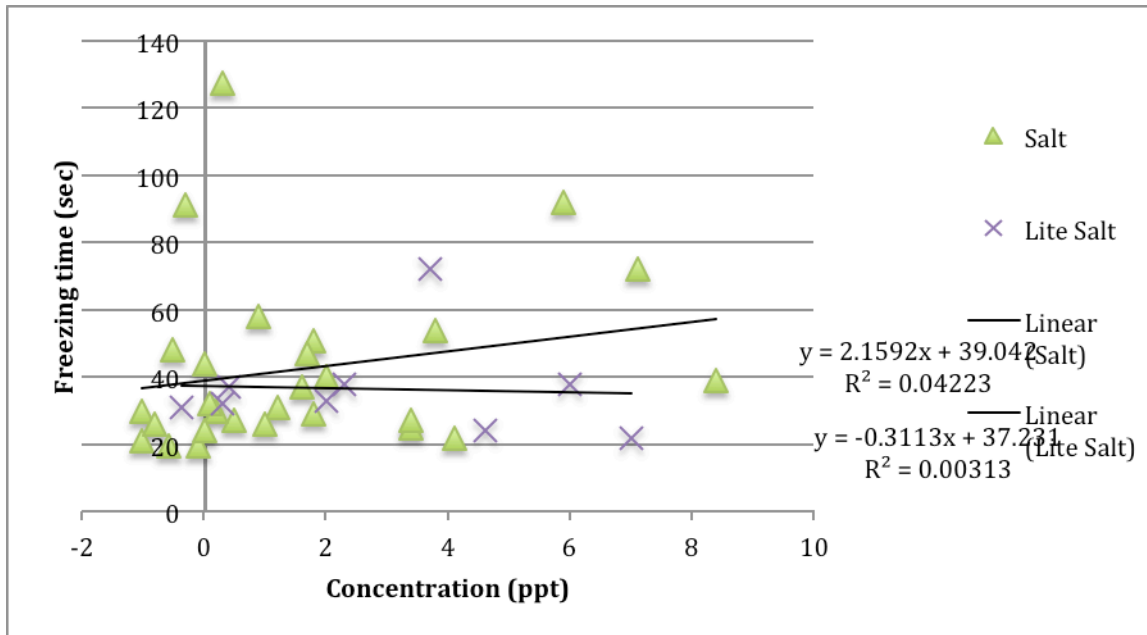


Figure 2. Effect of solute concentration on characteristic freezing times of potatoes in -65°C ethanol bath.



The freezing times were determined by measuring the time between the initial freezing point of the potato slice and the point where the potato slice reached a temperature of -10°C.

The results indicate that an increase in concentration of solute decreases the length of time required for freezing. One explanation is that since the sodium reduced the freezing point of the

water in the potatoes, it took less time for the final temperature to be reached after the initial formation of ice crystals. The effects of concentration were more pronounced for the slow freezing potatoes because the water molecules had more time to set up their formation before the temperature could drop. In the quick freeze, the components of the potato were solidifying too rapidly for the solute to make a difference on the crystal formation speeds.

Concentration vs. Hardness

It was predicted that samples that had absorbed a higher concentration of a given salt would have a lower hardness value. There did not seem to be a significant relationship between the absorbed concentration of the solute and the final hardness value in any circumstance. The slowly frozen samples that were microwaved tended to have higher hardness values than the samples that were thawed at room temperature. The quickly frozen samples had similar hardness values whether the samples were thawed at room temperature or in the microwave. The potatoes with the lite salt tended to have lower hardness values than the potatoes with the regular salt. The differences were more pronounced in the slowly frozen samples than in the quickly frozen samples. Figure 3 shows the differences between thawed and microwaved slices at the same temperature, while Figure 4 shows the differences between salt and lite salt on slices that were frozen at the same temperature and thawed at room temperature.

Figure 3. Effect of absorbed salt concentration on initial force applied to potatoes frozen at -21°C.

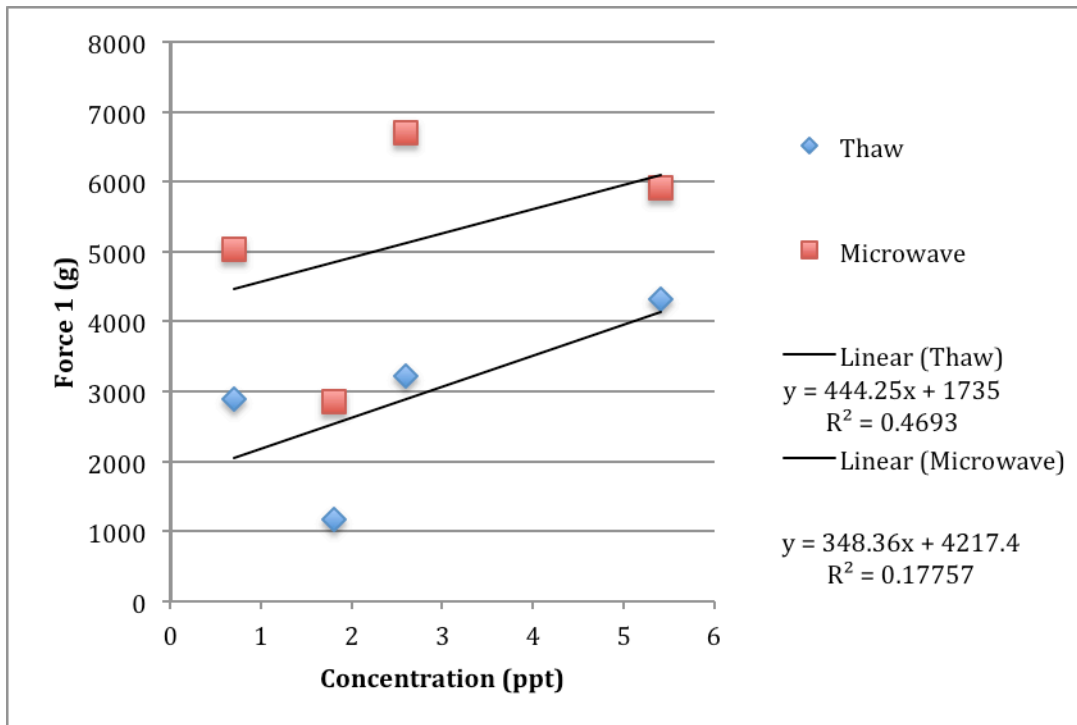
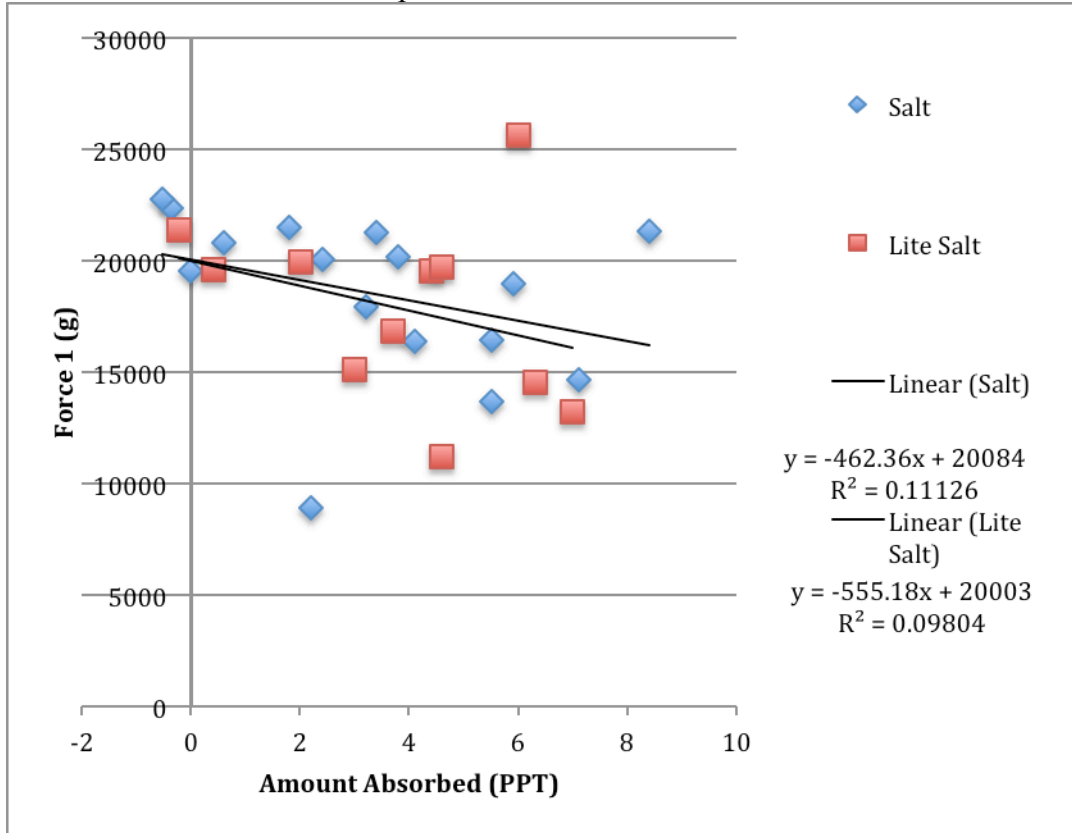


Figure 4. Effect of absorbed solute concentration on initial force applied to potatoes frozen at -65°C and thawed at room temperature.



The concentration of solutes in the potato slices may not have affected the size of the ice crystals that formed. Therefore, the concentration of solutes was not a factor that affected the hardness of the thawed potato slice. In the quickly frozen slices, the components solidified too quickly for the solutes to affect the size of the ice crystals. The smaller ice crystals means that the microwave could heat the potato slices more evenly. The relative speed in thawing the water in the microwaved slices means that there was less drip loss, and the cells in the potato held their texture better. The slower freeze allowed for larger ice crystals to form in addition to smaller ones, so there would be uneven heating and a reduced texture quality as a result.

Characteristic Freezing Time vs. Hardness

The prediction was that the samples that froze more quickly would have a higher hardness value. The slow freezing samples with salt had higher hardness values when the freezing rate was higher, which follows the prediction. The slow freezing samples with the lite salt had higher hardness values when the freezing rate was lower. The results for the quick freezing potatoes were more varied, but the thawed samples tended to have higher hardness values at low freezing rates, while the microwaved samples had lower values at lower freezing rates. The microwaved samples had higher hardness values than the thawed samples for the slow freeze, but the hardness values were more similar for the quick freeze potatoes. The salt samples had higher hardness values than the lite salt samples, although this difference was more pronounced for the slowly frozen samples compared to the quickly frozen ones.

Figure 5. Correlation between characteristic freezing time and initial force for potatoes with salt frozen at -21°C.

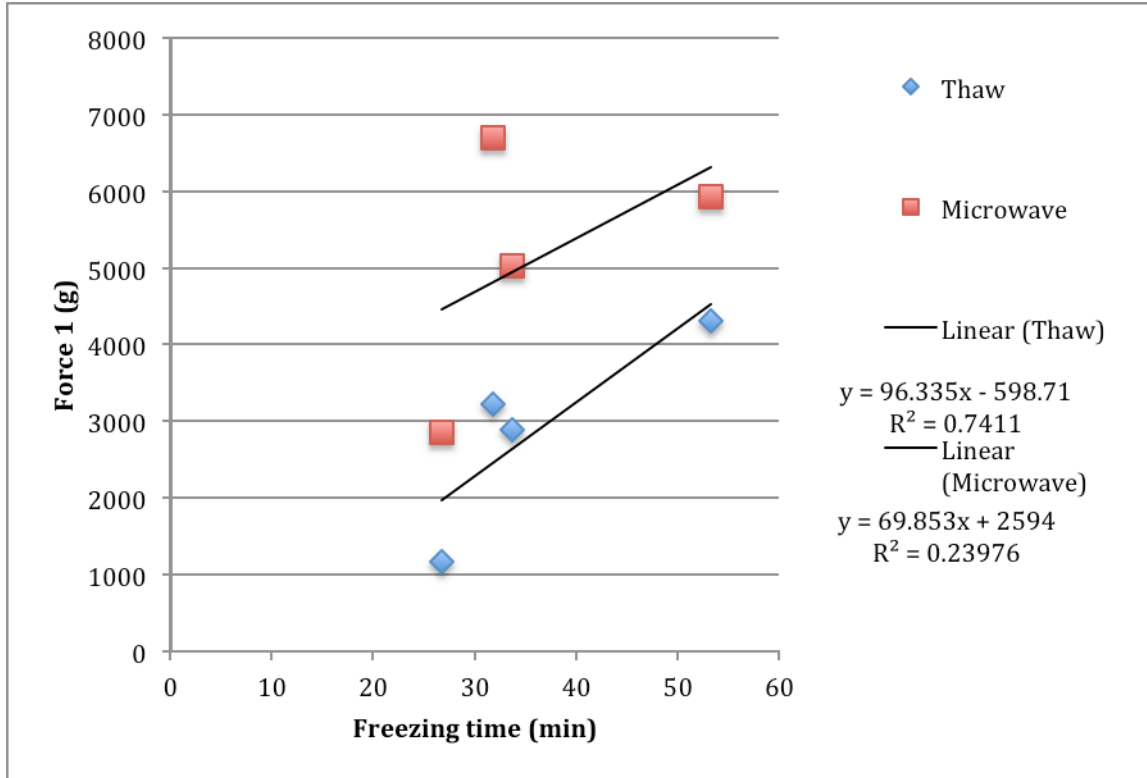
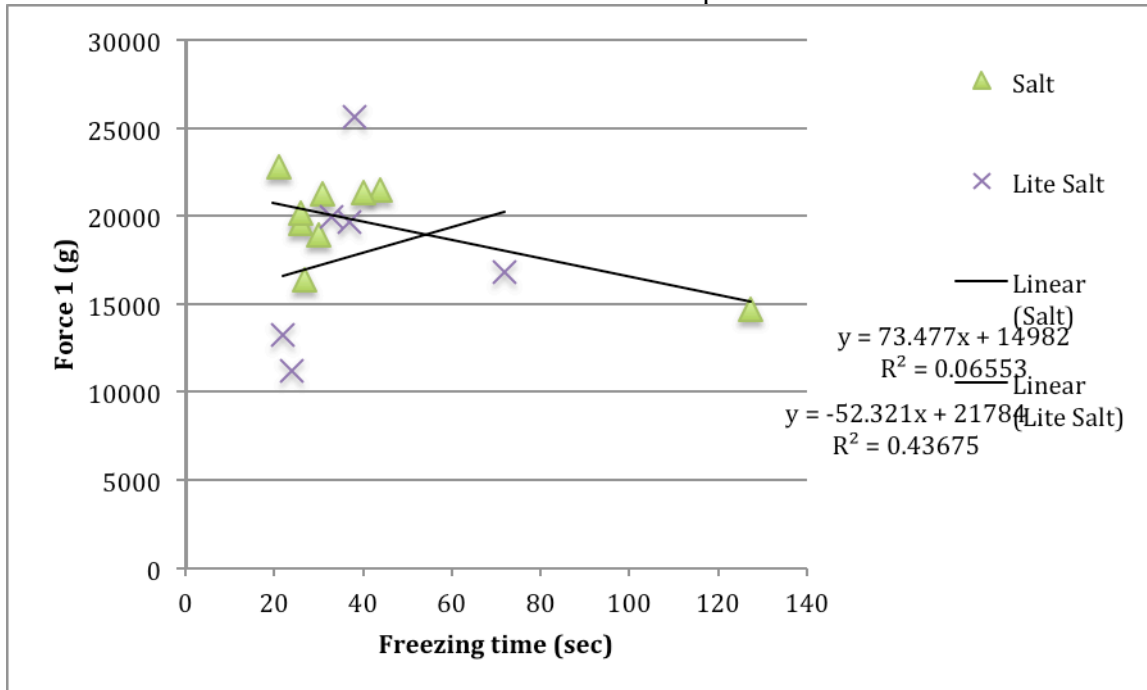


Figure 6. Correlation between characteristic freezing time and initial force for potatoes with different salts frozen at -65°C and thawed at room temperature.



The samples that were frozen at a slower rate have higher values for hardness because the slower freezing time allows for the development of larger ice crystals. The ice crystals disrupt cell membranes, which will cause the thawed product to be less hard. The small ice crystals from the quick freeze do not cause as much disruption, regardless of the type of salt. The salt had only one component that could be absorbed and affect the freezing properties of the potato, and since salt forms crystals easily it would make it easier for the ice crystals to align. The lite salt contains several different ions and molecules that can be absorbed by the potato, and they do not align to allow for ease of crystallization in the way that pure salt does. Therefore, it would take a little longer for this to freeze and result in larger ice crystals and a softer thawed product texture.

Conclusions

Potatoes tend to freeze more quickly when they have absorbed higher concentrations of salts. The concentration of the salts did not affect the hardness values of the thawed potatoes. Potatoes that were microwaved had a harder texture after thawing than those that were thawed at room temperature. The freezing rate was not affected by the use of a salt substitute instead of salt, but the texture of the potatoes was not as firm with the substitute. This study covered two methods of freezing, one of which was much quicker than the other. Further research can be conducted with other methods of freezing to investigate further how freezing rates affect hardness and are affected by solute concentrations. Other substitutes, especially potassium chloride, can be examined further as well.

References

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