The Effects of Adding Carrageenan on the Viscosity, Flavor, and Overall Consumer Preference of a Homemade Macaroni & Cheese Sauce

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Abstract:

The characteristics such as viscosity as well as consumer preference in the adjustment in levels of carrageenan when added to a homemade macaroni and cheese sauce were compared. Two levels of Viscarin carrageenan (both with Iota and Lambda forms) were used in the sauce. .3 percent and .5 percent levels were both analyzed. Viscosity, using the Brookfield Viscometer was used, along with ratings from a sensory panel (n = 29) in hedonic rating, overall flavor and mouth feel, and a structural descriptive test. The .5% level of carrageenan (highest amount) provided the most viscous product, least overall preferred flavor, and was the most viscous product as perceived by sensory analysis. The control sample with no added carrageenan had the most negative responses in consumer preference. As determined by instrumental viscosity analysis, values for viscosity decreased with increasing spindle speed characterizing thixotropic rheology. .3% level of carrageenan (intermediate amount) provided the intermediary viscosity, most overall preferred flavor, and was preferred when rated on a hedonic scale.
Introduction:

According to Tate & Lyle’s August 2005 Food Product Design pamphlet, carrageenan provides a texture that enhances taste. Homemade macaroni and cheese has no flavor enhancers, stabilizers, or fillers that could contribute to a more powerful cheese flavor. Mouth feel, taste, and texture, all affect the way consumers perceive its taste, and the level of thickening agent increases a product’s viscosity which releases flavor components of a product in a slower manner; thus yielding a higher perceived flavor level. Adding carrageenan to a home made macaroni and cheese sauce may exhibit similar flavor enhancement by increasing the viscosity of the cheese sauce; thereby, providing a more intense and preferred product. Viscarin carrageenan is a mixture ratio of iota and lambda carrageenans and reacts with calcium ions to form a gel. When the carrageenan is mixed in with a cheese sauce, it forms a solution. When it begins to cool after preparation, a gel begins to form. The calcium ions attract the sulfate groups within the carrageenan and form what’s called an aggregated gel.

Of total weight in grams of the sauce components (1045 g total; grated sharp cheddar cheese, and white sauce that consisted of flour, margarine, salt, and milk), .3% (3.135 g) and .5% (5.225 g) carrageenan was calculated and measured and added to separate sauces and incorporated completely by stirring. Since the sauce is being heated while stirring, the viscosity does not increase with increasing agitation, so incorporation into the sauce by stirring did not affect its rheology.

The purpose of this experiment is to investigate the relationship between the addition of carrageenan to a cheese sauce and its characteristics of viscosity in relation to flavor perception. Adjusting the amount of carrageenan in the sauce in amounts of .3% and .5% when compared with the control will result in an increased viscosity as well as a higher flavor perception and sensory
preference. The null hypothesis is: The addition of carrageenan does not have an effect on mouth feel and flavor of a home made macaroni and cheese sauce.

Analysis with the Brookfield Viscometer was used as the only objective method, and two sensory methods were used (hedonic rating and structured descriptive test), as it better illustrated the focus of this experiment in consumer taste perception.
Methods:

A recipe was taken from the F&N205 Food Science Laboratory Manual. The recipe is for a regular macaroni and cheese sauce that involves grated cheese and a white sauce. It was altered to fit the design of this experiment by changing it from an oven-baked macaroni and cheese to a regular cheese sauce that is mixed in with macaroni noodles. The control was the macaroni and cheese sauce with no carrageenan added. Variable #1 was a macaroni and cheese sauce using .3% carrageenan added, and Variable #2 was preparation of macaroni and cheese sauce with .5% carrageenan added. The white sauce (flour, margarine, salt, milk) was prepared and carrageenan was added. The carrageenan was added to the white sauce before the shredded cheese was added, and stirred until smooth and fully incorporated. 1 cup of cheese sauce from each of the variables was placed in a separate beaker to be tested using the Brookfield Viscometer. This was such that the sauce depth was up to the immersion groove on the spindle shaft. Spindle #5 was used for all samples of cheese sauce, and rotations per minute (rpm) were used at the 6, 12, and 20 intervals. The machine was reset each time the rotations changed for each interval of rpm. Each sample was analyzed with the Brookfield Viscometer separately in each of the three levels of rotations before the next sample was analyzed. Viscosities for Sample 703 at 6, 12, and 20 rpm was recorded, and reset between each interval, and then the next sample was analyzed. No calibration of instruments was done. Data was collected for viscosities for three different trials for triplicate data collection (See Table 1).

The remaining sauce was then added to macaroni noodles for the panel’s sensory analysis. A spatula was used to fully mix the sauce with the macaroni noodles to ensure full mixing of the sauce.
Triplicate data was analyzed by replicating the experiment for all three trials in all analyses (viscometer readings and sensory panel results).

The experiment was replicated, as stated above, at three different trials. Each of the samples was given a 3-number code (703, 407, 217) in order to randomize the treatments, and each sample was presented to the sensory panel in random order (i.e. the control sample was not presented as the first or the last sample for tasting in any of the three trials). For each trial, the 3-number codes remained the same to avoid confusion when analyzing data. All samples were presented in plain ceramic bowls, with index cards placed below each bowl with its sample number given. Each sensory panelist was given a paper plate and plastic fork to taste each sample. Each bowl had 1 spatula for distribution of samples by each panelist. Panelists were asked to sample from each bowl and to rate them on the score card accordingly. Sample 407 was the control sample with no carrageenan added to the sauce, sample 217 had .3% carrageenan added to the sauce recipe, and sample 703 had .5% carrageenan added to the sauce recipe.

The sensory scorecard that was used is given below:

Score Card:

You are given 3 different samples of macaroni and cheese. They all have different variable amounts of carrageenan in it, which may affect the flavor, texture, and mouth feel of the product. Please rate the samples accordingly.

Rate Sample 703 by checking the appropriate box

<table>
<thead>
<tr>
<th>Dislike Extremely</th>
<th>Dislike Very Much</th>
<th>Dislike Moderately</th>
<th>Dislike Slightly</th>
<th>Neither like nor dislike</th>
<th>Like slightly</th>
<th>Like moderately</th>
<th>Like very much</th>
<th>Like extremely</th>
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<tr>
<td>□</td>
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</table>

Rate Sample 407 by checking the appropriate box

<table>
<thead>
<tr>
<th>Dislike Extremely</th>
<th>Dislike Very Much</th>
<th>Dislike Moderately</th>
<th>Dislike Slightly</th>
<th>Neither like nor dislike</th>
<th>Like slightly</th>
<th>Like moderately</th>
<th>Like very much</th>
<th>Like extremely</th>
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</tbody>
</table>
Rate Sample 217 by checking the appropriate box

<table>
<thead>
<tr>
<th>Dislike Extremely</th>
<th>Dislike Very Much</th>
<th>Dislike Moderately</th>
<th>Dislike Slightly</th>
<th>Neither like nor dislike</th>
<th>Like slightly</th>
<th>Like moderately</th>
<th>Like very much</th>
<th>Like extremely</th>
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</table>

Rate Samples (703, 407, 217) for texture against the descriptive terms below.

Not viscous
Slightly viscous
Moderately viscous
Very viscous
Extremely viscous

Which sample did you think had the overall best flavor? (703, 407, 217)

The sensory panel completed the sensory scorecard accordingly. The recipe that was used to illustrate the principles stated above was adapted and adjusted from Food Science Laboratory Manual written by Karen Jamesen published in 1998:

*Macaroni & Cheese* (done for each trial)
- 168 g macaroni pasta
- 169.5 g grated mixed cheese
- 3 c medium white sauce (below)

*White sauce*:
- 84 g margarine
- 43.5 g all-purpose flour
- 9 g salt
- 711 ml (3 c) 1% milk (739 g)
- 3.135 g carrageenan (.3% version)
- 5.225 g carrageenan (.5% version)
Melt margarine. Stir in flour and salt. Stir in milk. Bring to a boil, cook on low heat 5 minutes. Add carrageenan (none, .3, .5%). Add cheese and stir until smooth (approx. 20 strokes). Add to cooked macaroni.

Discussion:

Calculating the weight of carrageenan to use in each variable was done as follows:

Total weight of sauce ingredients: 169.5 g (cheese) + 84 g (margarine) + 43.5 g (all-purpose flour) + 9 g (salt) + 739 g (1% milk) = 1045 g

1045 g x .003 (3%) = 3.135 g added to white sauce for 3% carrageenan recipe

1045 g x .005 (5%) = 5.225 g added to white sauce for 5% carrageenan recipe

Carrageenan, derived from seaweed, is from an Irish moss. After it is dried and ground, it is used in various applications such as ice cream crystal stabilization, prevention of oxidative rancidity in meats, and stabilizers in salad dressings. Carrageenan is used to replace fat as well as a flavor enhancer in many foods, and especially cheese products, which thus changes the texture and viscosity of the food (Konuklar et al, 2004). It is widely known for its use in dairy products like puddings, chocolate milk, and cheese products. Its structure is a complex mix of sulfated polysaccharides and comes in 3 different prototypes: kappa, iota, and lambda. These are based on the placement of two oddities: sulfate groups, and 3,6-anhydro rings, and association with anions like Potassium, Calcium, and Sodium. The iota form of carrageenan forms elastic gels in the presence of calcium ions, and is freeze/thaw stable, without going through syneresis (Daniel, 2005). In the dairy industry, carrageenans are widely known to interact with casein protein molecules and form networks which have an effect on the changing viscosity and interacting to produce a gel-like
structure, although the interaction mechanism between the casein molecules and carrageenan is not fully established.

The protein components in dairy products like cheese with lambda carrageenan especially is the most well documented interaction of carrageenan in terms of stabilization, elasticity, and viscosity (Camacho et al, 1998). The lambda carrageenan provides a thickening reaction in aqueous solutions, since it does not include an anhydrogalactose residue like the other types of carrageenan. Iota carrageenan does have this anhydrogalactose residue that allows it to form gel structures. When these structures form double helices, the rheological properties are affected. A concentration of .2 wt% of iota carrageenan has shown to exhibit effective soft gelling behaviors. In solutions that contain lambda carrageenans, noticeable changes in viscosity and elasticity were observed when the temperatures were above 40 degrees Celsius (Shchupunov, 2003). .3 and .5% variations were chosen because they were common carrageenan concentrations used in experiments to observe changes in rheological behavior, and readings on a Brookfield Viscometer were taken at 6, 12, 30, and 60 rpm in previous experiments in such applications (Ozdemir and Sadikoglu, 1998). Since the macaroni and cheese sauce was heated to boiling before the carrageenan was added, there should be noticeable differences in the viscosity and elasticity in the sauce variations. Viscarin carrageenan was used because of its use in dairy products since it is a combined mixture of iota and lambda carrageenans. Carrageenan, guar gum, and xanthan gum have been shown to produce higher viscosities in milk products, and carrageenan specifically has also been used to form gels with milk upon reaction with calcium ions. The stabilization of the network from milk components affects textural properties (Salvador and Fiszman, 1998). A lowered temperature or introduction of salts promotes the helical conformation in the development of the gel. Iota carrageenan, which is the largest constituent of Viscarin carrageenan, forms a gel in the presence of calcium which is present
in the cheese sauce in the recipe. The reason why the combination of iota and lambda carrageenan was useful in this application is because the lambda carrageenan enables the iota carrageenan to form a soft and weak gel that is yet sturdy enough to exhibit higher viscosity properties as seen in macaroni and cheese sauce (Velde et al, 2002). Kappa carrageenan is not incorporated into the copolymer of Viscarin carrageenan since it forms a strong and brittle gel. Iota and lambda carrageenan combined combines a strong thickened characteristic of the lambda content, and the soft elastic gel characteristic from the iota content (Bixler, 1994). The FMC Corporation develops a commercially available form of carrageenan for use in the dairy industry and is used with increasing percentages in weight in the effects of viscosity in skim milk and is analyzed using a stress rheometer. It was predicted in the Journal of Food Science that samples treated with increased carrageenan solutions would exhibit Newtonian behavior. Results showed that there was a correlation of an increased viscosity in skim milk as a function of temperature and carrageenan concentration; thus, thixotropic characteristics (Anderson et al, 2002).

It was observed in this experiment that due to the helical development in the structure in the interaction between the carrageenan from interaction with calcium ions, that a soft gel matrix was formed when both the .3 and .5% intervals of carrageenan were used in the cheese sauce. The .5% carrageenan resulted in a thicker, more viscous product as seen in Figure 1. The viscosity of sample 703 (.5% carrageenan) had the highest average viscosity out of all 3 trials; 47720. This is because the greater concentration of carrageenan in the sample, the greater the increase in viscosity (Shchupunov, 2003). This thixotropic behavior is also exhibited in the .3% carrageenan sample, but did not have as big an effect on the viscosity as the .5% (Figure 2), since it is shown that the viscosity is higher, but was very similar with that of the control sample.
The control, as expected, was the least viscous of the 3 samples (Figure 3 and Table 1), and was actually the least favored overall (Figure 4) by the sensory panel (6 out of 27 responses; 2 panelists did not answer this question on the score card). The intermediary concentration of .3% carrageenan was the most preferred in overall best flavor, as shown in Figure 4, with the .5% carrageenan as the next preferred sample. This was not expected since the .5% carrageenan provided a very viscous sauce which may have resulted in a lower preference and flavor palatability. This shows that an increasing amount of carrageenan still contributes to overall flavor potential (Foster, 2005).

Structured descriptive ratings showed that the .5% concentration of carrageenan showed to be most commonly recorded as “very viscous” (n = 8). Panelists rated the intermediary concentration of carrageenan (.3%) as moderately viscous (n = 14), and as expected and the average rating for sample 217 was 6.10 which was a higher average rating than the other two samples. The standard deviation for sample 217 is 1.988, which while it is close to up to 2 levels difference, it still had the higher average description (most preferred out of the 3 samples). The control sample with no amount of carrageenan added was only slightly viscous (Figure 5). Panelists rated on hedonic scales separately for each sample. There was not much difference in taste preference between the control and .5% concentrations (Figures 6 and 7); although, there were slightly more responses that showed preference for the control sample more so than the .5% concentration of carrageenan. There are 8 negative responses for both the control and the .5% samples (to the right of “neither like nor dislike”). It is still hard to tell which is more preferred based on the hedonic scales of the control and .5% carrageenan (Figures 6 and 7). It is shown in Figure 8; however, that the .3% carrageenan sample had most common responses of “like slightly”, “like moderately”, and “like very much,” illustrating the principle that an intermediary concentration of carrageenan in a low percentage of
.3% (when .1-1.0% is the preferred range) results in higher consumer preference (Goncalves, 2005). The standard deviation for the .5% carrageenan sauce was 1.639 with an average rating of 5.45 which is closer to “neither like nor dislike.” This is very similar with sample 407, the control, because this sample’s average rating was 5.52 and standard deviation of 1.975 which is also close to “neither like nor dislike.” The control sample did, however have higher (more preferred) average responses than the .5% carrageenan sauce, which is not what the results in Figure 4 illustrate. Figure 4 illustrates that even the .5% carrageenan sauce was more preferred than the control sample, while the average response is higher for the control sample when a sensory panel completed a sensory card hedonic scale. This makes it difficult to determine which sample was more preferred when not considering the intermediate level of carrageenan: is the control or .5% carrageenan preferred?

Obviously, the .3% recipe was most preferred out of all 3 samples, but what about the least preferred samples? It is difficult to see this relationship.

Carrageenan does increase perceived flavor with low concentrations, based on the overall response of best flavor (Figure 4). The sample with .3% concentration of carrageenan results in an increased viscosity that is not too thick, but viscous enough to slow down the release of flavor components from the food to taste receptors. When a higher concentration than this is used; however, viscosity may or may not have beneficial outcomes, this mainly depends on the consumer’s preference.

My overall P value was .126. This is not a low enough P value to reject the null hypothesis, that there is no effect on the mouth feel and overall flavor of the added carrageenan in the macaroni and cheese sauce. We have to accept the null hypothesis; that there is no effect.
Future Work:

There are many ways in which this experiment could be improved in the future with other researchers. The following ways to adjust the application of carrageenan in this experiment are ways in which was seen as sources of error. Carrageenan should be dissolved slowly and evenly before the cheese is added. This helps incorporate the carrageenan so there is even viscosity throughout the entire mixture. It would be wise to measure the water activity of the sauce as well as do a linespread apparatus, to see if those two factors are affected by the addition of carrageenan. The temperature should be recorded at which the carrageenan is added; therefore identical sauce pans should be used to heat the sauce mixture would have helped in the first trial. Different sized sauce pans were used for Trial 1, which may have resulted in unequal temperature which could affect the rate of dissolution of carrageenan. The speed of adding the carrageenan to the white sauce prior to the addition of cheese should be controlled in future experiments. This was probably the main source of error, and it is the reason for such a high viscosity reading in the first trial of sauces (Table 1), because the carrageenan was not added slowly to the sauce, and leaded to clumping of the sauce with very viscous areas. Time prior to adding the cheese should be recorded to ensure that heating of the white sauce and carrageenan is identical. A 3\textsuperscript{rd} variable might be considered if researchers wanted to investigate consumer preference for a product like this. A level higher than .5% should be used to differentiate between preferences of an even higher amount of carrageenan in a cheese sauce. In addition, larger intervals of carrageenan concentration should be used (larger than .2% between levels) so there might be a clearer distinction of preference among the sensory panelists. Some sources of error could also be due to the sensory panel mixing up the samples on their testing plate when they sampled the different variables. Perhaps 1 plate designated for each sample would have been beneficial to the distinction of samples so there is no confusion.
**Results:**

Table 1:

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Spindle Speed (rpm)</th>
<th>Trial #</th>
</tr>
</thead>
<tbody>
<tr>
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<td>15470 9100 6580</td>
<td>Trial 1</td>
</tr>
<tr>
<td>31530</td>
<td>21930 14000</td>
<td>Trial 2</td>
</tr>
<tr>
<td>26330</td>
<td>14870 10280</td>
<td>Trial 3</td>
</tr>
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<td>703</td>
<td>32800 20730 15800</td>
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</tr>
<tr>
<td>58130</td>
<td>32800 19300</td>
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<td>58530</td>
<td>32100 19960</td>
<td>Trial 3</td>
</tr>
<tr>
<td>407</td>
<td>22270 13370 8900</td>
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</tr>
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<td>29000</td>
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</tr>
<tr>
<td>19730</td>
<td>11870 8720</td>
<td>Trial 3</td>
</tr>
</tbody>
</table>

**Figure 1. Viscosity as a Function of Force**

Sample 703
Figure 2. Viscosity as a Function of Force
Sample 217

Figure 3. Viscosity as a Function of Force
Sample 407
Figure 4. Rating of Overall Best Flavor

Figure 5. Structured Descriptions of Samples as a Function of Viscosity
Figure 6. Hedonic Rating of Sample 407
Figure 7. Hedonic Rating of Sample 703
Figure 8. Hedonic Rating of Sample 217

Sensory Descriptions of .3% Carrageenan

- Dislike Extremely
- Dislike Very Much
- Dislike Moderately
- Dislike Slightly
- Neither Like/Dislike
- Like Slightly
- Like Moderately
- Like Very Much
- Like Extremely

# of Responses

- Dislike Extremely: 2
- Dislike Very Much: 4
- Dislike Moderately: 6
- Dislike Slightly: 9
- Neither Like/Dislike: 6
- Like Slightly: 6
- Like Moderately: 2
- Like Very Much: 1
- Like Extremely: 1
References:


Goncalves, Bruno Lamas. FMC Corporation; Phone Interview, October 6, 2005 3:45 pm.


