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RESEARCH ARTICLE

Using Egg Replacers in A Custard Style Pumpkin Pie

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Abstract

This paper represents a project completed in an experimental food class at the University of North Carolina at Greensboro, as a component of the DPD program in preparing students to enter a Dietetic Internship. The project focused on egg replacers that generally are utilized by vegans or egg allergic individual in baking. In this instance the egg replacer's chia seeds, flax seeds and whey protein isolate.

Keywords: Vegan Diets; Chia Seed; Flaxseed; Whey Protein Isolate; Custards

Introduction

Eggs are omitted from the diet for a variety of reasons ranging from personal preference to food allergies [1]. Those who maintain a vegan or lacto-vegetarian diet exclude eggs from their diet. Others may choose to limit their egg intake due to perceived health benefits. Some religions prohibit egg consumption, including Hinduism, Jainism, and Buddhism. Consuming eggs may pose severe health threats to people with egg allergies. Eggs are one of the top eight allergens and are the second most common allergen among children, affecting 1.3% of American children [2, 3]. In contrast, the prevalence of egg allergies among adults in the United States is 0.3%. The avoidance of eggs has resulted in a demand for acceptable egg replacers due to their central role in baking, affecting taste, texture, appearance, and mouth-feel of products [4] While the food industry has produced egg replacers for baking, there is little research on the utilization of egg replacers in custard type desserts, such as pumpkin pie.

Background

Egg substitutes are manufactured products that contain primarily egg whites to market a healthier, cholesterol free product [4]. Egg replacers, on the other hand, contain no egg components and are used in place of a whole egg [5]. Research on egg replacer has focused on economic benefits [6]. Egg replacers could potentially reduce manufacture costs [7]. Research on egg replacers increased following a reduction in egg availability [8]. With the use of egg replacers, manufacturers can meet increasing consumer demand for vegan and vegetarian products [9].

Egg replacers studied in food science research include formulations mainly with whey protein isolate or concentrate, hydrocolloids such as xanthan gum, and various plant protein isolates such as soy, pea, and wheat gluten [5, 6, 9]. To a lesser extent, chia seeds have also been used as an egg replacer [9, 10]. Xanthan gum is used as an egg replacer in gluten free baking [11-13]. While both chia seeds and flaxseeds are common egg replacers, currently there is limited research on flaxseed as an egg replacer. Because flaxseeds contain the same gum as chia seeds, it is logical to assume that this seed would also provide a viable egg replacer [14]. Food science research has studied the use of egg replacers in flour based products such as cakes, breads, muffins, and cookies often on a percentage flour basis [5, 6, 9, 10, 13-16]. Because pumpkin pie does not contain flour, egg replacers in this experiment were incorporated on either a protein equivalent or egg equivalent replacer basis.

Hypothesis

Common egg replacers will produce an acceptable texture in a pumpkin custard product as compared to standard pumpkin pie made with whole eggs.

Methodology

Preliminary experiments were conducted to examine the likelihood of developing an acceptable product with one of the selected egg replacers. The team expressed concern that whole chia seeds might create an unappetizing texture and visual appeal. A trial pie was prepared using ground chia seeds which were ground by hand with a mortar and pestle. The next pie was made without eggs or egg replacers. Both preliminary pies were made with the same recipe. Both experimental pies were

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acceptable in taste and texture. All necessary ingredients and equipment were procured, including Libby's canned pureed pumpkin, McCormick cloves, McCormick dried ginger, McCormick cinnamon, McCormick nutmeg, Harris Teeter brand eggs, Harris Teeter brand sweetened condensed milk, Morton iodized salt, Harris Teeter Brand pre-made pie crusts, Bob's Red Mill flaxseed meal, Spectrum whole chia seeds, Bob's Red Mill xanthan gum, and 90% whey protein isolate.

On the day of preparation, the oven was preheated to 425 degrees Fahrenheit. The pumpkin puree, sweetened condensed milk, salt, and spices were added to mixing bowls of identical Kitchen Aide mixers. The salt and spices were added. After grinding the chia seeds with a mortar and pestle, the chia seed egg replacer was prepared by combining 4 teaspoons of ground chia seeds and 6 tablespoons of boiling water. The flaxseed meal egg replacer was prepared by combining 2 tablespoons of flaxseed meal and 6 tablespoons of lukewarm tap water. Both chia seed and flaxseed egg replacers rested for 5 minutes to allow the gel to set up. Next 74.12 grams of water, 15 grams of whey protein isolate, and ⅛ teaspoons xanthan gum were combined. Either the eggs or egg replacers were added to the appropriate mixing bowl indicated.

All pies were placed in the same oven at the same time. After 15 minutes, the oven temperature was reduced to 350 degrees Fahrenheit. After baking for an additional 35 minutes, the pies were checked for doneness. The pies required different lengths of baking times. The pie made with flaxseed meal was removed after the initial 35 minutes at 350 degrees F, as recommended by the recipe. The pie made with whey protein required an additional 5 minutes of baking time. The pie made with whole eggs required an additional 10 minutes of baking time. The pie made with chia seeds required and additional 20 minutes of baking time. After cooling at room temperature for 4 hours, the pies were tested with a penetrometer. The pie heights were assessed at the center of the pies by measuring with a ruler. Sensory testing was done the next day, with all pies refrigerated overnight.

Subjective Testing Description

Subjecting testing examined taste and texture of the pumpkin pies with a group of untrained tasters. Pies were divided into 28 small slices, allowing testers to have 3-4 bites of each sample. Each sample was indicated using a random 3-digit number, which was generated with a random number generating tool by Google to eliminate tester bias. The generated numbers included 126 representing the ground chia seed variation, 770 representing the flaxseed meal variation, 897 representing the whey protein and xanthan gum variation, and 365 representing control pie prepared with whole eggs. The testing participants were given a cup of cold water, a plate with the sample variations, and a plastic spoon, along with a testing form and pencil. Testers were asked to rate the overall taste and overall texture of each pie variation, using a 5-point Likert Scale, 1 being very acceptable, 2 being somewhat acceptable, 3 being neutral, 4 being somewhat unacceptable, and 5 being unacceptable.

Subjective Testing Form

Test Day Verbal Instructions

Take a small bite of each sample while taking into consideration the overall taste and texture of each sample. Fill out the subjective testing form. Start with any sample and proceed in whatever order you wish.

Subjective Testing Form

Please rate the following on a 5 point scale:

1=Very acceptable 2=Some what acceptable 3=Neutral 4=Somewhat unacceptable 5=Unacceptable

	Sample 126	Sample 770	Sample 897	Sample 365
Overall Taste:				
Overall Texture:				

Objective Testing Description

The objective tests were completed with a penetrometer, toothpick, and ruler. The height of each pie was assessed with the use of a toothpick and ruler. The pies were expected to have variations in heights because eggs can ensure that a baked product has trapped air and other ingredients throughout the product, causing an increase in height [17]. After cooling to room temperature following baking, a toothpick was inserted in the center of each pie for height measurement in centimeters. All heights were recorded on the form shown below.

A penetrometer was used to assess the gel strength of the pumpkin pies. The gel strength was expected to vary between the pies due the role of eggs in developing a protein matrix [2]. The replacement of eggs with products that have different macronutrient ratios and composition were expected to cause a change in penetrometer readings. The pies were cooled to room temperature for 4 hours after baking. A biscuit cutter was used to remove a circular cutout from the center of each pie, including the crust. The pumpkin pie cutouts had diameters of about 3.5 inches. Next the penetrometer reading was performed on each cutout. The standard penetrometer procedure was used. Each circular cutout was positioned under the needle portion of the penetrometer. After storing the pies and center cutouts in the same refrigerator for 22 hours, a penetrometer reading was completed once again with the same center cutouts. Before refrigeration the pies and cutouts were gently covered with plastic wrap. The penetrometer readings were indicated on the form below. The differences in height and gel strength were expected to indicate how each egg replacer compared in replicating egg-like properties in pumpkin pie.

Objective Testing Form

Control Pie (Whole Eggs)	Penetrometer Measurement Room Temperature mm Refrigerated mm	Height Measurement _____cm

Variation 1: Ground Chia Seed	Penetrometer Measurement	Height Measurement
	Room Temperature mm Refrigerated mm	_____cm

Variation 2: Flaxseed Meal	Penetrometer Measurement	Height Measurement
	Room Temperature mm Refrigerated mm	_____cm

Variation 3: Whey Protein and Xanthan Gum	Penetrometer Measurement	Height Measurement
	Room Temperature mm Refrigerated mm	_____cm

Results

The results compared the gel strength, height, overall subjective taste, and overall subjective texture of the pie variations. In accordance with the hypothesis, the analysis of the results will focus on comparing each pie variation with a control pie prepared with whole eggs.

The penetrometer readings that were completed after cooling the pies to room temperature for 4 hours were 55 mm for the ground chia seed variation, 77 mm for the flaxseed meal variation, 45 mm for the whey protein and xanthan gum variation, and 58 mm for the control. The penetrometer reading for the pie made with ground chia seeds was 5.17% lower than the control. The penetrometer reading for the flaxseed meal pie variation was 32.76% greater than the control. The penetrometer reading for the pie made with whey protein powder and xanthan gum was 18.18% lower than that of the control. A higher penetrometer reading indicates weaker gel strength. The penetrometer readings indicated the whey protein and xanthan gum variation produced the strongest gel. The chia seed variation was the second strongest, followed by the control. The flaxseed variation had the weakest gel strength.

After chilling the pies under refrigeration for 22 hours, the penetrometer readings were 33 mm for the ground chia seed variation, 44 mm for the flaxseed meal variation, 25 mm for the whey protein and xanthan gum variation, and 42 mm for the control. The penetrometer reading of the pie made with ground chia seeds was 21.43% lower than that of the control made with eggs. The penetrometer reading of flaxseed meal pie was 4.76% greater than the control. The penetrometer reading of the pie made with whey protein powder and xanthan gum was 40.48% lower than the control. The order of strongest to weakest gel strength did not change after refrigeration. At room temperature, the pumpkin pie variation made with ground chia seeds had gel strength similar to the control pie at room temperature. After 22 hours of refrigeration, the pie made with flaxseed meal had gel strength similar to the control pie.

The pie made with ground chia seeds had a height of 6.5 cm. The pie variation prepared with flaxseed meal had a height of 8 cm. The whey protein and xanthan gum pumpkin pie variation had a height of 7.5 cm. The control pie had a height of 8 cm. The flaxseed meal variation was the same height as the control pie made with whole eggs. The pie prepared with ground chia seeds was 18.75% shorter than the control pie and the pie prepared with whey protein and xanthan gum was 6.25% shorter than the control pie.

After analyzing the subjective test results, 25 testing forms were included in the final analysis. As to overall texture of the pie prepared with ground chia seeds, 16 testers rated it as very acceptable, 6 testers rated it as somewhat acceptable, 0 testers rated it as neutral, 2 testers rated it as somewhat unacceptable, and 1 tester rated it as unacceptable. The overall texture of the pie prepared with flaxseed meal was rated as follows: 6 testers rated it as very acceptable, 9 testers rated it as somewhat acceptable, 4 testers rated it as neutral, 4 testers rated it as somewhat acceptable, and 2 testers rated it as unacceptable. For the overall texture of the control pie prepared with whole eggs, 12 testers rated it as very acceptable, 4 testers rated it as somewhat acceptable, 5 testers rated it as neutral, 3 testers rated it as somewhat acceptable, and 1 tester rated it as unacceptable. The overall texture of the pie prepared with whey protein and xanthan gum was rated as follows: 15 testers rated it as very acceptable, 8 testers rated it as somewhat acceptable, 2 testers rated it as neutral, 0 testers rated it as somewhat acceptable, and 0 testers rated it as unacceptable. With a lower score indicating a higher overall texture acceptability rating, the average rating for overall texture of each pie was as follows: 1.64 for pie prepared with ground chia seeds, 2.48 for the pie prepared with flaxseed meal, 1.48 for the pie prepared with whey and xanthan gum, and 2.08 for the control pie prepared with whole eggs.

The ratings of overall taste of the pie prepared with ground chia seeds were as follows: 15 testers rated it as very acceptable, 5 testers rated it as somewhat acceptable, 3 testers rated it has neutral, 1 tester rated it as somewhat unacceptable, and 1 tester rated it as unacceptable. For the pie prepared with flaxseed meal, the overall taste ratings were 7 testers rated it as very acceptable, 9 testers rated it as somewhat acceptable, 7 testers rated it has neutral, 2 testers rated it as somewhat unacceptable, and 0 tester rated it as unacceptable. The ratings for the overall taste of the pie prepared with whey protein and xanthan gum were as followers: 15 testers rated it as very acceptable, 7 testers rated it as somewhat acceptable, 3 testers rated it has neutral, 0 testers rated it as somewhat unacceptable, and 1 tester rated it as unacceptable. The overall taste of the control pie was rated as follows: 11 testers rated it as very acceptable, 6 testers rated it as somewhat acceptable, 7 testers rated it has neutral, 1 tester rated it as somewhat unacceptable, and 0 testers rated it as unacceptable. The average overall taste rating for each pie was 1.72 for the pie prepared with ground chia seeds, 2.16 for the pie prepared with flaxseed meal, 1.52 for the pie prepared with whey protein and xanthan gum, and 1.92 for the control pie.

Food Science Concepts

An average whole egg is approximately 74% water, 13% protein, and 11% fat [18]. This macronutrient ratio and composition dictates functionality in food products. Eggs play many important roles in baked goods such as binding, leavening, viscosity, tenderizing, volume, texture, stabilization, emulsification, foaming, coagulation, flavor, color, and nutritional value [6]. Specifically in custard-based desserts, egg proteins unfold during baking and create a matrix that traps water, milk fat globules, and other ingredients [15]. The egg yolk phospholipid, lecithin, aids by homogenizing the water and fat components within the matrix [18]. An effective egg replacer is an ingredient(s) that can closely mimic these characteristics. The amount of 90% Whey Protein Isolate (WPI) used was determined by matching the same amount of egg protein (12g (USDA food composition database) per recipe. The same amount of water equivalent to the two eggs per recipe was added, after subtracting the 3.7% moisture content of the WPI [19].

The WPI achieved a protein matrix similar to eggs. Its gelling capacity is a result of water solubility and binding which increases viscosity [15]. Xanthan gum, a type of polysaccharide, stabilized the WPI matrix by inhibiting excessive protein crosslinking [4]. This action of a carbohydrate on a protein containing mixture is known by some as "curdling insurance". Xanthan gum is a highly effective water-binding hydrocolloid [7, 20]. It acted as an emulsifier by thickening the pie mixture and suspending the ingredient molecules which prevented them from coalescing [20- 22]. Xanthan gum is such a powerful ingredient that only small amounts can make a significant difference [11]. Xanthan gum's properties combined with the gelling ability of the WPI ultimately produced the strongest gel matrix penetrometer reading.

Chia and flax seeds have a similar nutrient profile. Whole chia seeds contain around 25-35% fat, 15-25% protein, and 18-30% fiber and whole flax seeds contain 35-45% fat, 20-30% protein, and 20-30% fiber [10, 14, 23-25]. While both of these seeds contain protein and may have constituted a gel structure, the amount of protein per recipe would have been around 2g or less [26, 27]. The ingredient most likely to lend egg-like characteristics to the pie variations was the soluble fiber, or mucilage, content of each of these seeds. Chia seeds contain between 5-10% mucilage and flax seeds contain about 8% [23, 24, 28]. Mucilage is a gum contained within the seed coat that when released by grinding up the seeds, forms a thick gel with water [14].

This gel not only thickens the pie mixture, providing a hydrocolloid property, it has been cited as an emulsifier and foam/volume stabilizer [9, 14]. The chia seed variation may have produced the strongest penetrometer reading because the seeds were more finely ground (by the mortar and pestle) than the flaxseed meal resulting in a larger release of polysaccharide. This pie also stayed in the oven the longest, resulting in water evaporation. This may have also contributed to this pie having the shortest height (Table 1, 2) (Figure 1, 2, 3)

Objective Testing			
Pie Variation	**Penetrometer** Room temperature (mm)	**Penetrometer** Refrigerated (mm)	**Height (cm)**
Chia	55	33	6.5
Flax	77	44	8
Whey	45	25	7.5
Egg	58	42	8

Table 1

Percent Change in Objective Tests from Egg Variation			
Pie Variation	**Penetrometer** Room temperature	**Penetrometer** Refrigerated	**Height**
Chia	-5.17%	-0.43%	-18.75%
Flax	+32.76%	+4.76%	0%
Whey	-18.18%	-40.48%	-6.25%

Table 2

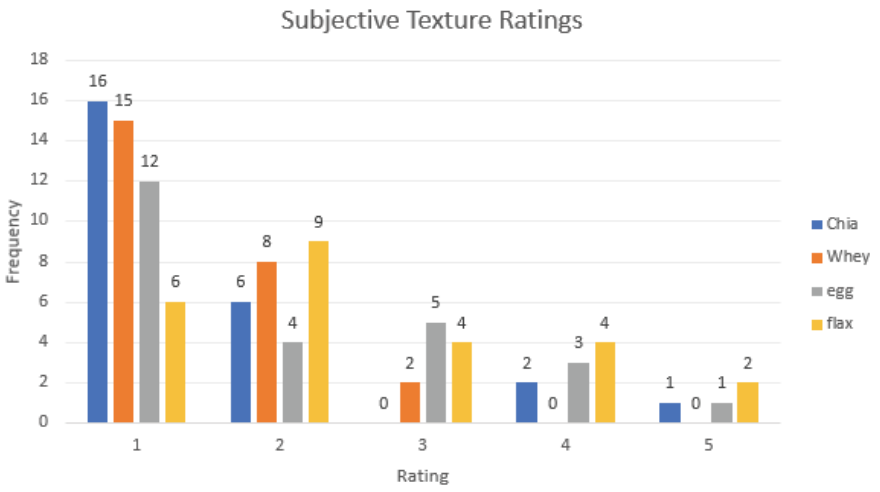

Figure 1

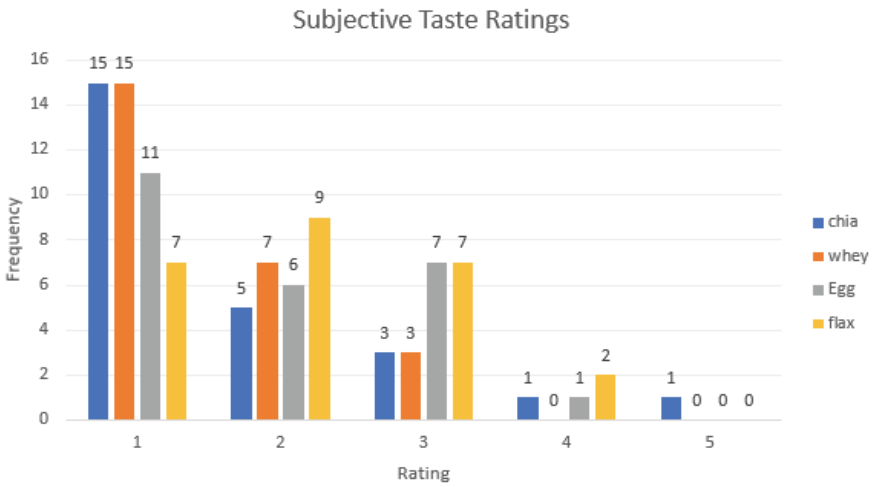

Figure 2

Figure 3: Plates of Pie Variations for Subjective Testing

Conclusion

The subjective results of this experiment showed that all three of the tested egg replacers produced an overall acceptable pumpkin pie in terms of taste and texture. The pumpkin pie variation with chia seeds as an egg replacer produced a gel matrix strength closest to the control pumpkin pie. The pumpkin pie variation made with flaxseed meal produced a pie with the same height as the control, although the WPI/xanthan gum variation was similar. Surprisingly, the overall subjective taste and texture acceptability ratings showed that the WPI/xanthan gum pie variation held a higher acceptability with testers than the control pie.

The chia seed variation's average subjective ratings were similar to the WPI/xanthan gum ratings, showing that this variation was also more preferred than the control pie. The flaxseed meal replacer variation scored the lowest for overall average subjective taste and texture which may have been related to the level of grind and water temperature. Overall, each variation scored on average above the neutral ratings and into the "somewhat acceptable" and "very acceptable" ranges. This data supports the hypothesis, showing that these common egg replacers are capable of producing an acceptable pumpkin pie taste and texture compared to the standard, egg-containing pumpkin pie.

Limitations

A major limitation of this experiment was difficulty in calibrating the oven. An estimated temperature increase to the oven temperature was necessary to achieve the correct oven thermometer reading. The temperature may have shifted throughout the baking process and affected the final results. Another limitation was that the flaxseed meal was not as finely ground as the ground chia seeds. The flaxseed meal was pre-packaged, whereas the chia seeds were ground by hand with a mortar and pestle. Perhaps if the consistency of the flaxseeds and chia seeds were the same, their use as a suitable egg replacer in pumpkin pie would be more comparable. Another

limitation is that the flaxseed meal was mixed with room temperature water and the ground chia seeds were mixed with boiling water. The difference in water temperatures may have influenced the potential of each seed to create and egg replacer gel. The baking times required to completely bake each pie was different for the control and the variations, affecting the taste and texture of each pie. Another limitation is that there was lecithin present in the pre-packaged whey protein isolate. Lecithin is an emulsifier and may have influenced the texture and subsequent subjective rating of that pie. A major limitation of the subjective testing was that the testers were completely untrained, as these were fellow students in the class.

Implications

The results of this research will be valuable to consumers, as the results show that all three of the variations of egg replacers could produce an acceptable product. Consumers who avoid eggs now have easily accessible, shelf stable egg replacer options for recipes using 2 or less eggs. Producers can acceptably use WPI/xanthan gum as an egg replacer to produce a more cost effective, low fat product, or use either flaxseed or chia seed to give a higher fiber, omega-3 fat containing product. Both chia seed and flaxseed are trendy items that could be used in marketing to increase sales.

Future research now has a reasonable basis to pursue flaxseed as an egg replacer option. With further studies, these seeds should be milled to the same level of grind compared to chia seed and use the same temperature of water when producing the gel. Research might also experiment with reducing the gel before incorporating it. Egg replacer research in custards is nil. This research paves the way for future study using chia seeds, flaxseeds, WPI, and xanthan gum as egg replacers in custard-based products.

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