Formulation and Sensory Analysis of a Ketogenic Snack to Improve Compliance with Ketogenic Therapy

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Limited dietary choices in the ketogenic diet may compromise compliance and reduce overall quality of life, and the low provision of fiber may further diminish quality of life. The purpose of this study was to develop highly acceptable high fiber, ketogenic snacks. Broccoli bites and crab rangoon were developed approximately at a 3.5 to 1 ketogenic ratio. The snacks were formulated using fiber isolates, pea hull fiber, hydroxypropyl methylcellulose and inulin as an alternative breading for frying. Sensory evaluation was carried out by students and staff at the University of Florida to determine the acceptability of overall taste, mouthfeel, and appearance of the snacks. Using a hedonic scaling method, panelists (n=67) determined acceptability, with 1 indicating extreme dislike, and 9 indicating extreme liking. For the broccoli bites, the mean hedonic rankings for overall taste, mouthfeel, and appearance were 6.54 ± 1.78 (mean ± SD), 6.27 ± 1.71, and 5.85 ± 1.73, respectively. For the crab rangoon, the mean hedonic rankings for overall taste, mouthfeel, and appearance were 5.60 ± 1.86, 4.93 ± 2.00, and 5.79 ± 1.78, respectively. In addition, hedonic rankings for the overall taste, mouthfeel, and appearance for the crab rangoon were rated as 6 (like slightly) or higher by 58.2%, 47.8%, and 67.2% of panelists, respectively. Hedonic rankings for the overall taste, mouthfeel, and appearance for the broccoli bites were rated as 6 (like slightly) or higher by 76.1%, 73.1%, and 62.7% of panelists, respectively.

Introduction

The ketogenic diet, first developed in the 1920s, is widely used to treat intractable epilepsy. Originally, bromides and phenobarbital were used for the treatment of epilepsy. The heavy sedating effects of these antiepileptic drugs contributed to the acceptance of ketogenic therapy in treatment of intractable epilepsy. Hugh Conklin, an osteopathic physician, believed that epilepsy was caused by intoxication of the brain from substances originating in the intestines (Freeman and Kossoff, 2007). Conklin hypothesized that putting the intestines at rest would prevent intoxication and prevent seizures. Conklin used “water therapy” to treat epilepsy, giving nothing but water for as long as 25 days. Conklin reported prolonged reduction in seizures activity, and news of his findings spread rapidly (Freeman and Kossoff, 2007).

The discovery that diets high in fat and low in carbohydrates could mimic starvation gave rise to ketogenic therapy. Ketogenic therapy consists of a high fat (up to 90% of total intake), low carbohydrate, and adequate protein diet. The mechanism behind the neural protection of ketogenic therapy remains a mystery, but in many cases is very effective in treating intractable epilepsy. Ketogenic therapy has been shown to reduce seizures by >50% in 60-75% of children who maintain ketogenic therapy (Freeman and Vining, 1998). The dietary restrictions of ketogenic therapy are accompanied by psychosocial issues: patients feel isolated from peers because they eat completely distinct foods (Pfeifer and Thiele, 2005).

GI disturbances are frequently reported among KD patients with nausea/vomiting, diarrhea, and constipation being most common (Kang and Chung, 2004). The restriction of carbohydrate in ketogenic therapy limits intake of fiber, and may be a factor contributing GI disturbances. Dietary fiber is derived from the cell wall of edible plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with partial or complete fermentation in the large intestine (Nelson, 2001). Carbohydrates that are indigestible in the small intestine are fermented in the large bowel to produce short chain fatty acids (SCFA’s). Increased fiber intake reduces the risk of prevalent Western diseases ((McCleary and Prosky, 2001), and demonstrates the importance of maintaining a healthy gut. Insufficient intake of soluble and insoluble fiber in ketogenic therapy may impart additional stress, and potentially increase the frequency and severity of seizures.

Ketogenic therapy alters the metabolism of the brain by limiting carbohydrates and forcing the brain and body to utilize alternative sources of fuel. Utilizing fatty acids as energy substrates in times of food depravation is crucial for survival. The brains ability to adapt to these metabolic changes in times of starvation is thought to be the foundation of ketogenic therapy. Ketogenic therapy mimics starvation by limiting glucose and providing high amounts of fatty acids,
ultimately shifting the metabolism of the brain to utilize ketone bodies as a major fuel (Matthews and Van Holde, 2000).

Challenges of administration of ketogenic therapy can be contributed to numerous factors. An obvious obstacle is the lack of commercial foods that are consistent with the nutritional demands of ketogenic diet. A major hurdle in developing widely available ketogenic foods is creating foods that are acceptable amongst large populations. In order to have widely available foods compatible with ketogenic therapy a large enough market must exist to produce affordable products. Producing foods that are acceptable amongst the general public creates the possibility of marketing ketogenic foods within grocery stores, and making ketogenic foods widely available to patients utilizing ketogenic therapy. Meal components of ketogenic therapy must be viewed as typical for the average diet, and not therapeutic in nature to appeal to the average consumer. Creating foods that appeal to the average consumer, while therapeutic in composition, may be a promising approach to improving compliance with ketogenic therapy. Sensory evaluation could determine the acceptability of these foods amongst the normal population.

Affective tests measure subjective attitudes towards a product based on sensory properties. Affective testing methods may include paired comparison, hedonic scale, and ranking. Hedonic scaling tests are effective in measuring a degree of liking for a particular food product. Hedonic scaling is commonly performed with a nine point scale, ranging from “like extremely” to “dislike extremely.” A neutral response exists in the central location, with the response corresponding to “neither like or dislike.” Hedonic scaling is a useful tool in determining if a given food product would be successful in the marketplace.

The effects fiber intake of the efficacy of ketogenic diet are unknown, however, with isolated fiber (devoid of protein and with very low levels of available carbohydrate), we may be able to provide adequate levels of fiber in the ketogenic diet. Increasing fiber intake in the diet of those on ketogenic therapy has the potential to enhance quality of life while easing the burden of implementing ketogenic therapy. Through product development and sensory testing it may be possible to create highly acceptable foods that are compliant with ketogenic therapy.

Materials and Methods

Fiber isolates were utilized to supplement fiber into the ketogenic snacks, and sensory analysis was used to determine the acceptability amongst students and staff at the University of Florida.

2.1 - Product Development

Product development initially focused on designing a cracker type snack that may be consumed with, or between meals. After numerous attempts to formulate snack-like crackers, cookies, and breads, it became apparent that minimization of carbohydrate and protein content would limit the type of snacks that could be developed. Through trial and error, it was discovered that the fiber isolates, in combination with gluten, could function as a breading for fried foods. To formulate a snack that would provide maximum clinical effectiveness, it was necessary to minimize protein and carbohydrate content of the fiber breading, while maximizing fiber content.

The fiber mixture contained the protein gluten to provide stability to the fiber breading. The amount of protein used in the fiber mix was determined by reducing the gluten content until the fiber mix was unstable when fried. Gluten content was minimized as alternative sources of protein need to be included in the ketogenic diet. Guar was utilized to provide additional stability to the fiber breading when moistened with water. It was speculated that the absorptive capacity of guar was very effective in stabilizing the snack in the uncooked state. Also, guar seemed to form a protective barrier to oil when used in frying applications, as thermal gelation occurs when guar is exposed to high temperatures (Sahin and Sumnu, 2005). The ketogenic snacks contained a high fat content, mostly in the form unsaturated oils. The goal was to develop high fiber snacks compliant with ketogenic therapy (high fat, low available carbohydrate and protein) that were stable throughout the cooking process. The stability and consistency of the ketogenic snack was dependent on preventing the leaking of internal oils into the cooking medium. Hydropropyl methyl cellulose behaved similarly to guar when exposed to temperature extremes, forming a protective gel and stabilizing the ketogenic snack while cooking.

Initially, the fiber mix was combined with water and rolled thin in a dough-like consistency. The fiber mix was cut into 2in x 2in squares, stuffed with fillings, and folded into a triangle. The products were then fried, and sampled. A variety of fillings were sampled, including spicy chicken pizza, cheese sticks, vanilla ice cream, and cheese cake. Overall, this method of preparation proved to be very time-consuming. The products chosen for sensory analysis included crab rangoon, and broccoli bites. Instead of preparing in the manner previously mentioned, the broccoli bites and crab rangoon were dredged in a dry fiber mix, and then moistened with water. Moistening the fiber mix after coating the food products was more efficient in preparation.
time and consistency. Following a series of steps to achieve the desired products (see Appendix A & B), the ketogenic snacks were fried and stored for sensory evaluation to be performed at a later time.

The fiber mix consisted of Inulin (Fruitafit-TEX!, Sensus America Inc., Monmouth Junction, NJ, USA). Guar gum (3500F-D, Tic Gums, Belcamp, MD, USA). Hydropropyl Methyl Cellulose (Methocel A4M, Dow Chemicals, Midland, MI, USA). Gluten (Arise 8000, MGP Ingredients, Atchison, KS, USA). Pea Fibre (Best Pea Fibre, Best Cooking Pulses, Portage la Prairie, Manitoba, Canada). A dry mixture consisting of 33.5% inulin, 33.5% pea fiber, 23.5% gluten, 7.0% cellulose, and 2.5% guar was prepared. The dry ingredients were combined in a mixing bowl and mixed until a homogenous color and consistency was reached.

The ketogenic snacks products were prepared under commercial-like conditions in the pilot plant of the Food Science and Human Nutrition Department. The snacks were prepared at approximately a 3.5:1 ratio (3.5 parts fat to 1 part carbohydrate plus protein). The ratio of the ketogenic snacks were determined using an excel spreadsheet that yields accurate percentages of protein, carbohydrate, and lipid based on gram measurements of food items used to prepare the ketogenic snacks.

2.2 - Sensory Evaluation

Sensory evaluation was performed on both the broccoli bite (Appendix A) and crab rangoon (Appendix B) in the sensory lab at the University of Florida. Panelists signed informed consent (standing protocol #2003-U-0491).

Panelists were asked to respond to a series of demographic questions to determine age, gender, and frequency of fried food consumption. Panelists were given a small cup of water and crackers to cleanse their palate between samples. Panelists were presented with two foods samples, broccoli bite and crab rangoon, and responded to a series of computer generated questions (Appendix C) regarding the overall appearance, taste, and mouthfeel of the product being sampled. Panelists were also instructed to comment on appearance, taste, and mouthfeel.

Results

The resulting ketogenic snacks included broccoli bites (Appendix A) and crab rangoon (Appendix B) formulated at a ketogenic ratio of 3.47 to 1 and 3.42 to 1, respectively. Overall, 67 people including students and staff at the University of Florida participated in sensory evaluation. Hedonic scaling results for the overall appearance, taste, and mouthfeel of the broccoli bite and crab rangoon were 5.85 ± 1.72 and 5.79 ± 1.78, 6.54 ± 1.78 and 5.60 ± 1.86, and 6.27 ± 1.71 and 4.93 ± 2.00, respectively (Figure 1). In addition, hedonic rankings for the overall taste, mouthfeel, and appearance for the crab rangoon were rated as 6 (like slightly) or higher by 58.2%, 47.8%, and 67.2%, respectively. Hedonic rankings for the overall taste, mouthfeel, and appearance for the broccoli bites were rated as 6 (like slightly) or higher by 76.1%, 73.1%, and 62.7%, respectively. Figure 1 depicts the sensory evaluation hedonic results for overall appearance, taste, and mouthfeel of the crab rangoon, while figure 2 depicts the sensory evaluation hedonic results for overall appearance, taste, and mouthfeel of the broccoli bites.

![Figure 1: Sensory Results for Crab Rangoon](image-url)
Panelists were also asked to comment on the appearance, taste, and mouthfeel of the broccoli bites and crab rangoon. Comments for the broccoli bites included “looks crunchy, nice golden color”, “It's very good. It's a nice mix of natural, fried, and cheesy flavor. I would recommend this item because of the taste...seems like a perfect snack”, and “not very broccoli taste, sort of tastes like dirt with a gritty crust”. Comments for the crab rangoon included “batter looks crispy with some flakiness, looks good”, “no real shape, could be darker in color”, “I really like the fried taste and the gooeyness of the sample...YUMMY! It wasn't too fishy either”, and “it tastes like old bad tuna”.

Figure 3 depicts the demographic results for age and gender of the 67 panelists that participated in sensory evaluation are as follows. The majority of panelists fell between the ages of 18 and 24, with 30% of panelists reporting to be between 18 and 20 years of age, and 46% of panelists reporting to be between 21 and 24 years of age. The highest reported age was between 55 and 59 years of age.

Discussion

The purpose of the research project was to develop high fiber ketogenic snacks, and to determine the sensory acceptability of the developed food products. It has been shown that the developed high-fiber ketogenic snacks are acceptable sensory participants in this study, but acceptability amongst patients on ketogenic therapy is undetermined. Underlying factors that contribute to acceptability of the ketogenic snacks amongst the public are likely to influence acceptability amongst ketogenic patients. For instance, preferences for certain types of foods will have a major influence on acceptability, as was evident in sensory evaluation of the ketogenic snacks. Hedonic scaling results varied from a score of 1 (disliked extremely) to a score of 9 (liked extremely) for overall appearance, taste, and mouthfeel. The discrepancy in acceptability may be attributed to preference for certain types of food and methods of preparation. Interestingly, sensory panelists who consumed fried foods on an average of 6 times per year reported a lower acceptability for both ketogenic snacks in terms of overall appearance, taste, and mouthfeel with the exception of the overall appearance of the crab rangoon. It is expected that children who suffer from intractable epilepsy will have a greater preference for high-fat foods, however, it is not clear if ketogenic patients will prefer the types of ketogenic snacks evaluated by the students and staff at the University of Florida. Amari et al. (2008) has shown that children who have seizures show a significant higher preference for high-fat foods. The children who participated in this study had never been initiated on ketogenic therapy, but showed a significant preference for high fat foods when compared to a control group of children who did not have seizures. One child in the study with seizures stated that “this one makes me feel better” after consuming samples of butter, cream, cheese, and mayonnaise.

Development of the ketogenic snacks offered many challenges, but yielded a novel method of preparing ketogenic foods. Frying foods would be the ideal method of delivering high fat food items to ketogenic patients, but the usage of flours to bread foods prior to being fried presents many challenges. Using a fiber mix to replace the carbohydrates in flour creates an opportunity to provide fried foods to ketogenic patients. Fiber is similar in structure to carbohydrate, except it is indigestible by the humans. Interestingly, soluble fibers may be fermented by bacteria in the large intestine to yield short-chain fatty acids, as opposed to being broken down into mono and disaccharides for absorption. The effects of increasing the fiber intake of those on ketogenic therapy is uncertain, however, determining how fiber intake influences ketogenic therapy may present opportunities to improve the efficacy of ketogenic therapy.
Included in the fiber breading mix were gluten (wheat protein), guar (gum), hydropropyl methyl cellulose, inulin, and pea fibre. Gluten provided structure to the fiber mix, creating a protein matrix that stabilized the fiber mix when moistened. Hydropropyl methyl cellulose and guar form thermal gels at high temperatures, preventing the leakage and absorption of oils while cooking. Inulin and pea fibre were used to fortify the fiber mixture, and replace the digestible forms of carbohydrate commonly found in flour. The application of the fiber mixture is similar to the application of wheat based flours. 

Fiber intake, and the effects of fiber on those who suffer from intractable epilepsy, is a topic which needs greater exploration to determine the importance of fiber in the diet of ketogenic patients. The importance of fiber is well documented in the general population, but it is uncertain the effects that fiber supplementation will have on ketogenic patients. However, our current knowledge of fiber, and the role it plays in maintaining the integrity of the large intestine, indicates that the effects of fiber fortification in the ketogenic population may be beneficial.

The ethics of ketogenic therapy are called into question when considering the high fat, and often times, caloric restriction of ketogenic therapy. However, not implementing ketogenic therapy leaves few alternatives for those who suffer from intractable epilepsy. Individuals who are unresponsive to antiepileptic therapy in the form of pharmaceuticals are limited in options for the management of intractable epilepsy. Ketogenic therapy may be the most effective means of treating intractable epilepsy, as scientific studies support the theory that ketogenic therapy is more effective in treating intractable epilepsy than traditional pharmacological approaches. Justification for utilizing ketogenic therapy is evident when examining the beneficial effects of ketogenic therapy in managing intractable epilepsy, however, ketogenic therapy could be vastly improved by understanding the effects that dietary components such as fiber have on ketogenic patients.

To maximize the efficacy of ketogenic therapy, research is needed to understand the role of fiber in ketogenic therapy, and how it may influence patients on ketogenic therapy. Understanding the intestinal environment before and after supplementation with fiber may help to determine how much fiber is needed to maximize the efficacy of ketogenic therapy. High fiber ketogenic snacks may provide an adequate vehicle for the delivery of fiber, while possibly improving compliance with ketogenic diet. Further research is needed to determine how ketogenic snacks may impact ketogenic therapy, and if the ketogenic snacks are acceptable to those on ketogenic therapy.

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**Literature Cited**


Figure 3: Age and gender demographics for sensory panelists of ketogenic snacks
Appendix A

Broccoli Bites – Recipe

Yield: 16 – 6.5 oz Broccoli Bites
Serving Size – 4 ea
Servings - 4

Ingredients

32.5 g – Frozen Chopped Broccoli (thawed, rung dry, and chopped)
24.9 g – Sargento Cheddar Jack Cheese Blend (pre-shredded)
17.5 g – Canola Oil
7.5 g – Crisco (Trans-Fat Free)
31.1 g – Philadelphia Original Cream Cheese-Room Temp
10.0 g – Fresh Garlic (minced)
0.8 g – Kosher Salt
Oil for frying (amount will depend) on method used

Utensils for Preparation

3 Med Size Mixing Bowls
Cheesecloth or clean dry towel
Cutting Board
Chef’s Knife
3 Sheet pans
Wax paper
Digital food scale
Freezer Bags
Paper Towels

Utensils for Cooking

2 Qt Pot or Deep Fryer
Fry Skimmer

Preparation Directions

1) Allow broccoli to thaw overnight in refrigerator. If not completely thawed, run water over broccoli while still in package.
2) Slice cream cheese into smaller portions (2in x 2in), and allow to come to room temperature (about 1 hour).
3) Remove broccoli from package and rind dry using a clean dry towel or cheesecloth.
4) Roughly chop broccoli so that no large chunks are visible.
5) Place chopped broccoli in mixing bowl.
6) Mix cream cheese with broccoli.
7) Add remaining ingredients and mix thoroughly.
8) Refrigerate for 1 hour, or until chilled.
9) In small batches, weight out 6.5g portions of broccoli mix. Roll portions into ball shape, place on sheet pan covered with wax paper, and freeze. Repeat process until all mix has been weighed, shaped, and froze (Figure A).
KETOGENIC SNACKS

Fig. 1: rolled, shaped, and frozen
Fig. 2: freeze in fiber mix
Fig. 3: breaded product

10) Once completely frozen, remove broccoli bites from freezer and allow to sit at room temperature for five minutes. Using a spray bottle, lightly mist bites with water, and roll in hands to form a moist round ball.

11) Dredge bites in dry mix, and return to freezer while still in dry mix. Bites should be covered with dry mix (Figure B).

12) Allow outer coating to freeze (about 45 minutes), and remove from dry mix. Lightly mist with water, and toss lightly in dry mix (Figure 3).

13) Place coated bites on sheet pan covered with wax paper. Freeze bites until outer coating is completely frozen.

Cooking Instructions

1) Preheat deep fryer or fry oil to 350°F
2) Remove bites from freezer and very lightly mist with water
3) In small batches, fry bites for 15-25 seconds (If you will be eating immediately fry for 35-45 seconds).

4) Remove bites using skimmer, and lay on sheet pan covered with paper towels to absorb excess oil.

5) Once cool, place in freezer. For long-term storage, place bites in freezer bags once completely frozen.

6) To reheat, bake in over for approximately 15-20 minutes at 200°F, serve immediately.

Appendix B

Crab Rangoon Snacks – Recipe

Yield: 11 - 6.5 oz Crab Rangoon Snacks
Serving Size – 4 ea
Servings – 2.5

Ingredients

12.3 g - White Crab Meat
1.7 g - Fresh Ginger
8.2 g - Bok Choy
36.1 g - Philadelphia Original Cream Cheese
0.8 g – Green Onion
2.6 g – Worcestershire
7.0 g – Canola Oil
7.0 g - Crisco (Trans-Fat Free)
0.2 g – Guar Gum

Figure 4: Finished Product
**Utensils for Preparation**

- 3 Med Size Mixing Bowls
- Cutting Board
- Chef's Knife
- 3 Sheet pans
- Wax paper
- Digital food scale
- Freezer Bags
- Paper Towels

**Utensils for Cooking**

- 2Qt Pot or Deep Fryer
- Oil for frying (amount will depend on method used)
- Fry Skimmer

**Preparation Directions**

1) Drain excess water from crab meat.
2) Slice cream cheese into smaller portions (2in x 2in), and allow to come to room temperature (about 1 hour).
3) Cut tops and bottoms (1”) off of bok choy, and finely chop the remainder (use half greens and half stalk for mixture).
4) Place crab and bok choy into mixing bowl.
5) Mix cream cheese with crab and bok choy.
6) Add remaining ingredients and mix thoroughly.
7) Refrigerate for 1 hour, or until chilled (it may be necessary to cool in freezer to achieve desired shape as described below).
8) In small batches, weight out 6.5g portions of crab mix. Roll portions into ball shape, place on sheet pan covered with wax paper, and freeze.

Repeat process until all mix has been weighed, shaped, and froze.

9) Once completely frozen, remove crab rangoon from freezer and allow to sit at room temperature for five minutes. Using a spray bottle, lightly mist bites with water, and roll in hands to form a moist round ball.
10) Dredge crab rangoon in dry mix, and return to freezer while still in dry mix. Bites should be covered with dry mix (Figure 1).

**Cooking Instructions**

1) Preheat deep fryer or fry oil to 350°F
2) Remove crab rangoon from freezer and very lightly mist with water
3) In small batches, fry crab rangoon for 15-25 seconds (If you will be eating immediately fry for 35-45 seconds).
4) Remove using skimmer, and lay on sheet pan covered with paper towels to absorb excess oil.
5) Once cool, place in freezer. For long-term storage, place bites in freezer bags once completely frozen.

6) To reheat, bake in oven at 200°F for 15-20 minutes; serve immediately.

![Fig. 1: freeze in fiber mix](image1)

![Fig. 2: breaded product](image2)

![Fig. 3: Finished Product](image3)