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CAMP: Children's Acceptance of Muffins with Different Proteins

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Abstract

In 2019, around 40% of school-aged children in Arkansas were classified as overweight (~17%) and obese (~23%), according to BMI data collected. Children with obesity have an increased risk of developing type 2 diabetes, hypertension, and dyslipidemia. Unhealthy eating habits, such as skipping breakfast, have been strongly associated with overeating, weight gain and obesity. Breakfast is a key component of a healthy diet and can positively impact children's health and well-being. However, there has been a steady decline in breakfast consumption in US children over the past 40 years. Specifically, breakfast consumption declined among 8–10-year-old children by 9% and adolescents by 13-20%. In addition, in Arkansas, >300,000 (10% of the state's population) children receive free or reduced lunch and only 63.5% of these children participate in the School Breakfast Program. It has been established that protein is exceptionally important in regard to children's nutritional needs, growth, and development. It has also been proven that consuming protein in the morning with breakfast is exceedingly beneficial for children and may help reduce hunger and food intake. However, convenient, high-protein breakfast foods are lacking. In addition, children's acceptance of different protein sources such as pea protein or whey protein has not been studied. The original objectives of this project were to 1) develop a protein-based breakfast muffin for children using different protein sources, 2) to determine the effects of different protein sources on the sensory properties of muffins, and 3) to determine children's acceptance of different protein sources. However, due to the COVID-19 pandemic, we were only able to address objectives 1 and 2.

Introduction

Background and Need

The USDA has specific nutritional requirements for children that are expressed through the National School Lunch Program's guidelines. These guidelines discuss the importance of protein in a child's diet (*Discover MyPlate: Nutrition Education for Kindergarten*, 2019). While protein is only one of the key elements, it is one of the hardest ones to incorporate in a picky child's diet.

This leads into the importance of food acceptance for children. Food acceptance refers to the level of liking for a particular food (Meiselman & Bell, 2003). In order to keep children healthy, "acceptance of an adequate variety and quantity of food is essential" (Birch, 1987). One way to overcome this obstacle is to give children early experiences with food. The social context and physiological consequences of eating influence children's decisions of the quantity and variety of food they want to eat (Birch, 1987). Exposure is also crucial when it comes to children's acceptance of food. It was found that after exposing children to a different variety of foods in different amounts, preference was found to be an increasing function of exposure for both types of exposure: looking and tasting (Birch, 1987).

Protein is an extremely important nutrient for children. The amino acids lysine and arginine are found in protein and have been found to be factors in growth hormone release (Uauy et al., 2015). Protein intake of high-quality proteins have been found to be effective for good growth and is positively associated with height and weight (Uauy et al., 2015). Some studies have even suggested that dietary reference intakes (DRIs) for protein for an active child may underestimate their true needs (Volterman & Atkinson, 2016).

Breakfast is an essential meal when it comes to protein consumption. A breakfast that is high in protein and fat has been proven to result in higher diet quality without lowering feelings of satiation or satiety (Kranz et al., 2017). Studies show that the consumption of protein as a part of a breakfast containing carbohydrate is an important nutritional approach that enhances net protein balance (Karagounis et al., 2018).

Problem Statement

There is currently a large absence of information regarding children's acceptance of different proteins. It has been established that protein is exceptionally important in regard to children's nutritional needs, growth, and development. It has also been proven that consuming protein in the morning with breakfast is exceedingly beneficial for children. However, children's acceptance of different protein sources such as pea protein, whey protein, or soy protein, has not been researched. This information would be extremely beneficial for ensuring that picky eaters meet their protein requirements during breakfast because these specific proteins are easy to include in a more desirable, carbohydrate-dense breakfast item.

Purpose Statement

The purpose of this study is to determine the effects of different protein sources on muffin texture, moisture content, color, and volume and analyze these properties to predict children's acceptance of these muffins.

Research Questions

1. How accepting are children of different protein sources if it is given to them in a muffin form?

2. How do different protein sources affect muffin texture, moisture content, color, and volume?
3. How does the palatability of commercial muffins compare to that of high-protein muffins?

Literature Review

Many studies have been conducted on the effects of protein on the human body. While the studies are peer-reviewed and accurate, they fail to properly address the food acceptance patterns of children regarding different protein sources. Although the literature covers a wide variety of nutritional studies, this review will focus on themes that revolve around the incidence of childhood obesity, the role of breakfast, the importance of protein in a child's diet and the food acceptance patterns of children. These themes specifically include incidence of childhood obesity, child dietary and lifestyle choices associated with obesity, the role of breakfast, food variety in a child's diet, the role of protein in the diet of children, children's protein consumption at breakfast, different protein needs for physically active children, children's food acceptance patterns, and the rise of plant-based diets.

Incidence of Childhood Obesity

Childhood obesity is a serious public health concern due to the increasing prevalence of obesity worldwide (Cheung et al., 2016). According to a 2017 review, "the prevalence of severe obesity in children aged 2 to 19 years has continued to increase" in the United States (Kumar & Kelly, 2017). In the last 3 decades, childhood obesity has "more than doubled in children and tripled in adolescents" (Sanyaolu et al., 2019). Obesity can affect all aspects of a child's life including their psychological health, cardiovascular health, and overall physical health (Sanyaolu et al., 2019). In a 2019 study, obesity was defined as "a BMI of greater than or equal to the age- and sex-specific 95th percentiles of the 2000 Centers for Disease Control and Prevention (CDC) growth charts" (Sanyaolu et al., 2019). Many of the comorbidities encountered in children with obesity include "type 2 diabetes mellitus (T2DM), dyslipidemia, obstructive sleep apnea (OSA), and steatohepatitis" which used to be considered "adult" diseases (Kumar & Kelly, 2017). Due to the severity of these comorbidities, it is important that children and their families are encouraged to "select food groups of lower energy density…and [decrease] portion size" to increase weight loss (Kumar & Kelly, 2017). With this in mind, it is important to note the role that protein plays in a healthy child's diet. A recent study showed that increased protein consumption at breakfast led to "increased energy expenditure, fat oxidation, and higher satiety" (Kranz et al., 2017). This study and many others like it suggest that higher protein consumption in children may lead to better weight management and increased overall health.

Child Dietary and Lifestyle Choices Associated with Obesity

When it comes to food choices, "the availability of high-caloric, less-expensive food coupled with the extensive advertisement and easy accessibility of these foods has contributed immensely" to the high prevalence of obesity (Sanyaolu et al., 2019). Likewise, the number of children biking or walking to school today is only 16% "compared with 42% in the late 1960s" (Sanyaolu et al., 2019). Overall, certain behaviors have been linked to childhood obesity including a lack of physical activity and unhealthy eating patterns such as "eating more food away from home, more sugar-sweetened drinks, and snacking more frequently" which all result in excess energy intake. With proper education on the causes of childhood obesity, parents and caregivers "can help prevent childhood obesity by providing healthy meals and snacks" (Sanyaolu et al., 2019).

The Role of Breakfast

The daily consumption of breakfast is important to a child's overall health. Eating breakfast has been proven to improve the "overall quality and nutrient intake" of a child's diet (Chitra & Reddy, 2007). There is extensive literature showing a "clear overall nutritional benefit" associated with the consumption of breakfast (Gibney et al., 2018). On the other hand, skipping breakfast has been found to "hinder child growth" due to the body's natural mechanisms (Chitra & Reddy, 2007). When breakfast is skipped, the body will utilize its stores of protein in order to meet energy requirements, leading to protein imbalance. Skipping breakfast can also lead to "behavioral problems" as well as poor "cognition and academic performance" (Chitra & Reddy, 2007). The results of these studies indicate "the importance of providing at least a third of the day's requirement through breakfast" by educating parents with respect to "proper distribution of meals" throughout the day (Chitra & Reddy, 2007).

Food Variety in a Child's Diet

The USDA, who releases nutrition guidelines for Americans, recommends that a child's diet consist of a wide variety of healthful foods such as fruits, vegetables, carbohydrates, and protein. They also emphasize the importance of variety in a child's diet and encourage parents to allow their children to discover new foods (*Discover MyPlate: Nutrition Education for Kindergarten*, 2019). In a 2005 study, it was determined that high protein is a key factor in infant formula development, but differences between different protein sources were not explored (Seppo et al., 2005). This study revealed a major gap in nutritional research. While the benefits of protein were explored, the benefits and pitfalls of a variety of different sources of protein were not determined. There are many different protein sources that need to be explored such as whey protein that comes from animal sources and pea and soy protein that come from plant sources. These proteins are accessible and have been proven to be beneficial, but they have not been thoroughly compared. In recent years, a study was conducted that analyzed the growth and body composition of children who are picky eaters. This study revealed that children's picky nature leads to macro and micronutrient deficits and causes adverse effects on children's growth and development (Taylor et al., 2019). The study discussed the benefits of early identification, intervention, and growth surveillance in regard to children who are picky eaters.

Lack of variety in a child's diet is becoming a serious problem in the United States. A study conducted by Uauy in 2015 stated that over a third of all deaths of children under the age of five are linked to undernutrition (Uauy et al., 2015). The study also mentioned the importance of variety to combat undernutrition and ensure that children are growing (Uauy et al., 2015). Consuming a variety of foods is important for all humans, but children especially benefit from a varied diet due to their growing body's need for nutritional support.

The Role of Protein in the Diet of Children

Protein consumption plays an important role in children's health. Protein provides amino acids which are "combined in the body to create protein substances" essential for forming necessary body tissues and utilized as a "major component of the body's transportation system" (Menza & Probart, 2013). High quality proteins "have been found to be effective for [children's] growth" (Uauy et al., 2015). In fact, "protein intake in early life" has been found to be "positively associated with height and weight at 10 y of age" (Uauy et al., 2015). The current dietary protein requirement is 0.8 grams of protein per kg of body weight per day (Committee, 2005).

It is also crucial to mention the importance of complete proteins in the diet. Complete proteins are defined as protein sources that contain all essential amino acids. Most animal sources provide a complete source of dietary protein, whereas plant protein sources "generally lack one or more of the essential amino acids" (Hoffman & Falvo, 2004). It is important to mention that animal protein, despite providing all of the essential amino acids, has "health professionals concerned about the amount of saturated fat common in these foods compared to vegetable sources" (Hoffman & Falvo, 2004). The literature acknowledges the importance of complete proteins while also bringing to light the "potential health concerns" associated with a diet high in animal protein sources.

Children's Protein Consumption at Breakfast

Children need to consume a significant amount of protein at breakfast due to the increase in the rate of development throughout childhood. The inclusion of protein in children's breakfast increases feelings of fullness which contribute to energy balance and limit overconsumption (Kranz et al., 2017). It can also be concluded that the consumption of protein as a part of a breakfast containing carbohydrate is an important nutritional approach that enhances net protein balance over time (Karagounis et al., 2018). Studies also prove that spreading out protein consumption is crucial for improving nitrogen retention. Protein distribution also improves protein balance overnight until breakfast (Karagounis et al., 2018). These factors contribute to the increased prevention of obesity due to the onset of satiety. The inclusion of protein at breakfast has been proven to help kids stay fuller for longer and not overconsume calories (Kranz et al., 2017). Children who skip breakfast are at a higher risk of being overweight and unhealthy than those who consistently consume breakfast (Kranz et al., 2017). While protein, in general, is extremely important for growing children, protein distribution and the inclusion of protein at breakfast have shown huge benefits in children's development.

Different Protein Needs for Physically Active Children

While the studies above address the importance of protein in a child's diet, they fail to address the adjustments that need to be made to protein requirements for physically active children. A study conducted in 2016 analyzed the daily distribution of carbohydrate, protein, and fat intake in elite youth academy soccer players over a 7-day training period. This study was conducted to determine the dietary goals for elite youth players. The researchers found that protein was the only macronutrient that had an observed significant difference in total absolute energy between the two test groups (Naughton et al., 2016). The study recommended that child athletes focus on their optimal daily distribution patterns and consume more protein in hopes of increasing satiety while still consuming a substantial amount of energy (Naughton et al., 2016). Another study conducted in 2016 addressed the gap between dietary reference intakes for protein in adults and the complete lack of dietary reference intakes for protein in children. Volterman and Atkinson hypothesized that the protein needs of children may be smaller or larger than that of adults (Volterman & Atkinson, 2016). The study eventually concluded that children, especially active ones who are at their peak growth period, have distinct nutritional needs for dietary protein compared with adults (Volterman & Atkinson, 2016). The study also suggests that further research be done to focus on the protein needs of active children and the effects of chronic high intakes of macronutrients (Volterman & Atkinson, 2016). These two studies guide further research and address the lack of information and guidance regarding the protein needs of growing, active children.

Children’s Food Acceptance Patterns

One of the many things explored in this research was the food acceptance patterns of children and how these patterns are influenced. In 2002, Johnson conducted a study that evaluated the importance of providing a variety of foods to children and allowing them to determine how much they want (Johnson, 2002). The study also emphasized the benefits of offering appropriate foods for children at appropriate ages and the parents’ role as a nutritional mentor for their children (Johnson, 2002). A study conducted by Birch in 1987 addressed the role of experience in children's food acceptance patterns. During this study, Birch discovered that repetitive inclusion of a specific food in a child's meal increases the chance of the child liking that food (Birch, 1987). The study also discussed the success of using different food shapes to increase food acceptance. These two studies were extremely important resources for future research due to their connection to nutritional variety in children's diets. By addressing food acceptance and explaining the reasons behind a child's food preferences, researchers were able to explore children's acceptance of different foods with the background knowledge necessary to do so.

These studies allowed researchers to develop background knowledge on the effects of protein on a child's body and the importance of protein distribution and varied diet. They also allowed for the discovery of the gaps in research involving children's nutritional needs. These investigations revealed concepts that could be further studied such as the effects of chronic high intakes of macronutrients and the need for detailed protein requirements catered towards children. The studies cited above, while extensive, did not quite address the changes in children's food acceptance patterns regarding different protein sources.

The Rise of Plant-based Diets

The Dietary Guidelines for Americans attempt to encourage Americans to consume more fruits and vegetables to improve health (Agriculture, 2015). Many studies have found plant-based diets "to be associated with lower risk of cardiovascular outcomes and intermediate risk factors" (Satija & Hu, 2018). In fact, the Dietary Guidelines for Americans explicitly recommends "appropriately planned vegetarian diets" for improved cardiovascular and overall physical health. It is also important to note that "health benefits may be observed even with gradual reductions in animal food intake when replaced with healthy plant foods," meaning those with a moderate approach to a plant-based diet will still reap the benefits (Satija & Hu, 2018). The overwhelming evidence of the benefits of a plant-based diet has increased the diet's popularity and consumers' interest in plant foods.

Materials and Methods

The methodology of the study was essential for providing accuracy and validity to the research. This study utilizes a quantitative format for measuring moisture content, texture, color, and specific volume of various muffin recipes. Due to the COVID-19 pandemic, we were not able to test the acceptance of the muffin in children. Instead, we focused on developing the muffin recipes to meet protein goals and assessing the rheological properties of the muffins, comparing them to commercially available muffins targeting children.

Materials

Protein varieties were provided by Organic Unflavored Pea Protein Powder (Austin, TX) and Impact Whey Protein Powder (New York City, NY). Commercial muffin controls were purchased from Entenmann's (Horsham, PA). Other ingredients for making muffins were purchased at a local grocery store including bananas, blueberries, eggs, vanilla extract, almond milk, cinnamon, gluten free oat flour, baking powder, baking soda, butter, applesauce, and inulin powder.

Methods

Muffin Preparation

Ingredients listed previously were combined in a specific manner to create a desirable batter for all muffins within each recipe. The formulation was reproduced with an increase in only the protein content, to see how each protein affected the properties of the muffins. First, the oven was pre-heated to 425°F. Then, mashed banana, sugar, almond milk, applesauce, vanilla, and cinnamon were added to a large bowl and whisked until they were combined. Next, the flour, protein powder, baking powder, and baking soda were added. A standard muffin pan was lightly greased with vegetable oil spray. A standard batter of 24 muffins per batch was spooned into each greased liner and the tops were smoothed down for an even bake. The muffins were cooked in a conventional General Electric Company oven (Model JBS360RRSS, Boston, MA) preheated to 425°F (218 °C) for 5 min and then 350°F (177°C) for 15-20 min. Muffins were removed from pan as soon as the muffins were cool enough to handle. For each treatment, muffin batches were produced in triplicate.

Color and Texture Analysis

A Chroma Meter CCR-400 (Konica Minolta, Inc., Japan) was calibrated using a white tile before testing. Crust color was measured on the top of each type of muffin in triplicate. Color was expressed as L*, a*, and b* values. The rounded muffin tops were cut off to yield a muffin height of 2.5 cm to standardize and conduct texture analysis. Using a TA.XT Plus texture analyzer (Texture Technologies, Hamilton, MA, USA), triplicates of each type of muffin were tested for hardness, cohesiveness, sponginess, gumminess, and chewiness. After calibration of the equipment, individual samples were centered on a metal stand underneath a P/2 TA-25 2" cylinder probe. A program for muffins (Wardy et al., 2018) was chosen to run a 2-bite test with a 0.049-N trigger force and a wait time of 5 s between bites.

Moisture Content

Moisture contents of various protein concentrations were measured using convection oven drying method (Paz et al., 2020). Two-gram samples were heated to 130 °C until all moisture was evaporated. The difference in initial and final weight corresponded to moisture content. All samples were analyzed in triplicate.

Specific Volume

Volume of various protein concentrations were measured using the rate of displacement method. Greenhunter's Pride Game Plot Dutch Clover Seed (Green Seed Co., Inc., Springfield, Missouri) filled a glass jar and initial volume was measured using graduated cylinders. Each muffin was placed in the jar and seeds were poured in to fill space. The seeds used were then measured using graduated cylinders. The difference of initial volume versus displaced volume provided the final volume measurement. All samples were analyzed in triplicate.

Statistical Analysis

Data were analyzed for variance (One Way ANOVA) test. Results are reported as means ± standard deviation. All analyses were conducted using GraphPad Prism Software, version 8.3.1. Probability values (P values) less than or equal to $\alpha = 0.05$ were considered significant.

Results

A variety of muffin recipes were tested and modified to determine the best base recipe for the study. The recipe was a modified version of a recipe found online (Kitahara, 2020). Modifications throughout the testing process included adding peanut butter, doubling the protein content, tripling the protein content, adding applesauce, adding more dairy free milk, and adding inulin powder. Each of these modifications served a purpose. The goal of the recipe testing was to find a recipe that allowed for at least 10-15 grams of protein and around 5-8 grams of fiber per serving, but still had great flavor (Table 5). One serving was equivalent to 5 mini muffins. Each recipe was tested against another on a group of six friends and family members. The recipe that was rated higher was then tested again against a new modified recipe. This process was repeated until there were two recipes left. The difference between these recipes was the protein content. One recipe included doubling the protein content while the other tripled the protein content. A total of six recipes were selected (Table 6). A whey protein muffin with double the protein, a pea protein muffin with double the protein, a whey protein muffin with triple the protein, a pea protein muffin with triple the protein, a control muffin recipe (Burros), and Entenmann's Little Bites as the commercial muffin recipe. These recipes were tested for moisture content, texture, color, and volume. These sensory properties were chosen in order to compare the muffins palatability in a quantitative manner.

Color and Texture of the Muffins

Color and texture are two of the most important characteristics of any baked good when it comes to palatability. When a child picks up a muffin, they will first feel the texture and see the color of the muffin. In order to increase children's acceptance of the muffin, it is important that the product has similar color and texture characteristics to that of its sample, commercial counterpart, which has the desired characteristics. A greater L* value indicates a lighter color. With the commercial muffin being the lightest colored muffin, the muffin recipes with a greater L* value can be assumed to be more desirable (Table 3). The control muffin recipe had the second greatest L* value and it was determined that the addition of protein powder led to a darker muffin. With regard to lightness, the whey protein muffins had a more desirable color than the pea protein muffins, regardless of protein content. A positive a* value indicates a reddish hue as opposed to a negative a* value which would correspond to a greenish hue. The commercial muffins had an average a* value of 4.08 (Table 3). The muffin recipes with the most similar values were the pea protein muffins with triple the protein content and the whey protein muffins with triple the protein content. The average a* value for these muffins was 6.04 and 17.91, respectively (Table 3). Lastly, the b* value corresponds to blue/yellow hues. A positive b* value corresponds to a yellow hue whereas a negative b* value corresponds to a blue hue. The commercial muffins had an average b* value of 21.50 (Table 3), corresponding to a muffin crust that had a more yellowish hue. While the control muffins and the whey protein muffins with double the protein content had significantly higher b* values, 32.36 and 28.47 respectively, the remaining muffins had very similar values to that of the commercial muffin. The L* values of the whey protein muffins were the most noteworthy results from this color analysis because they revealed a similarity between the desirable commercial muffins and the whey protein muffins.

Various properties were measured to analyze the texture of the muffins including hardness, cohesiveness, springiness, gumminess, and chewiness (Table 4). Only the values of the control muffins were comparable to the commercial muffins. The protein muffins had significant statistical differences in regard to these properties (Figure 1b).

Moisture Content

Moisture content is another important property to consider when measuring the palatability of a food product. Similar moisture content would provide comparable mouthfeel and texture properties to the consumer, which would affect overall acceptance. The average percent moisture content of the protein muffins was much higher than that of the commercial and control muffins with the protein muffins ranging from 47.1% to 61.4% and the control and commercial muffins ranging from 23.9 to 27.5% (Table 2). The difference between the percent moisture content of the protein muffins versus the commercial muffins was significant for all protein muffin recipes (Figure 1d).

Specific Volume

Specific volume is another sensory property that determines palatability and acceptance of a food product. Muffins with a volume comparable to the commercial muffins that consumers are more familiar with would be more desirable and more widely accepted. The difference between the average specific volume of the commercial muffins versus the protein muffins is statistically significant for all the recipes except for the whey protein muffin with double the protein content (Figure 1c). The average specific volume of the whey protein muffin with double the protein content is 1.7 compared to 1.8 for the commercial and control muffins (Table 1). This means that the whey protein muffin with double the protein content has the most similar volume to the commercial muffin.

Discussion

The purpose of this study was to determine children's acceptance of different protein sources when given to them in muffin form. Due to the COVID-19 pandemic, testing the muffins on children in a laboratory setting was not feasible, so the muffins were tested for sensory properties that could be analyzed to determine the muffins palatability. The goal was to identify a muffin recipe that produced similar sensory properties to a desirable commercial muffin, but with a higher protein and fiber content to increase its nutritional value. Muffins with values that were not significant when compared to the commercial product would have an increased likelihood of consumer acceptance. As discussed in the previous section, the percent moisture content and texture of the protein muffins when compared to the commercial muffins was significantly different (Figure 1b- 1d). The only sensory properties that produced results with few significant differences were the color and specific volume of the muffins. Data from the Chroma Meter revealed that the whey protein muffins had closer L* values to the commercial muffins, making them more palatable (Table 3). However, when comparing a* and b*, the pea protein muffins with triple the protein content had values closer to those of the desirable commercial muffins (Table 3). When comparing the specific volume of the muffins, the difference between the whey protein muffins with double the protein content and the commercial muffins was not significant (Figure 1c). This means that the whey protein muffins with double the protein content are more similar in volume to the desirable commercial muffins than the other protein muffin recipes.

Conclusions

Based on sensory properties of the protein muffins when compared to the commercial muffins, the whey protein muffins with double the protein content would have a greater palatability and would be more widely accepted by children. Although these muffins had significantly different texture properties and percent moisture content values, they were very comparable to the commercial muffins due to their similar color lightness and specific volume. The statistical indifferences of these sensory properties suggest that a more nutritious whey protein muffin with double the protein content could be used as a substitution for a less nutritious commercial muffin. Further studies should focus on the direct relationship between these sensory properties and children's acceptance patterns. Comparisons of the quantitative data analyzing the sensory properties and the qualitative data from a questionnaire utilized during a randomized control trial would help establish a more concrete relationship between these sensory properties and children's acceptance.

Limitations

This research is subject to some limitations. First, the COVID-19 pandemic made testing the muffins on children in a laboratory setting unfeasible. Without this limitation, a more concrete relationship between the sensory properties and children's acceptance of the muffins could have been established. Second, there was a significant amount of variability that could be attributed to the use of blueberries in the muffin recipes. When baked, blueberries provide a large amount of unpredictability that can lead to a higher coefficient of variability in regard to the sensory properties analyzed. Removing the blueberries from all the muffin recipes would most likely decrease the variability and lead to more accurate data. Lastly, the initial muffin recipes were selected based on the preferences of participants who were recruited using convenience sampling. Randomly selecting participants would remove any convenience bias, provide a more balanced selection, and produce more accurate results.

Tables and Figures

Table 1 – Specific volume of muffins

Sample	Sample weight (g)	Rapeseed volume (mL)	Specific volume (mL/g)	Average specific volume	SD	CV
Commercial Muffin 1	12.46	22.0	1.77			
Commercial Muffin 2	12.34	23.0	1.86	1.8	0.05	2.8
Commercial Muffin 3	12.22	22.0	1.80			
Control Muffin 1	16.83	30.0	1.78			
Control Muffin 2	22.09	42.0	1.90	1.8	0.07	3.8
Control Muffin 3	14.60	26.0	1.78			
Whey Muffin (2X) 1	23.42	38.0	1.62			
Whey Muffin (2X) 2	23.45	39.0	1.66	1.7	0.03	1.7
Whey Muffin (2X) 3	22.07	37.0	1.68			
Pea Muffin (2X) 1	26.80	33.0	1.23			
Pea Muffin (2X) 2	25.98	29.0	1.12	1.2	0.08	6.9
Pea Muffin (2X) 3	25.04	32.0	1.28			
Whey Muffin (3X) 1	21.26	51.0	2.40			
Whey Muffin (3X) 2	25.73	65.0	2.53	2.4	0.08	3.3
Whey Muffin (3X) 3	22.73	54.0	2.38			
Pea Muffin (3X) 1	24.94	28.0	1.12			
Pea Muffin (3X) 2	24.90	28.0	1.12	1.1	0.00	0.2
Pea Muffin (3X) 3	24.12	27.0	1.12			

Abbreviations: 3X, triple protein; 2X, double protein; SD, standard deviation; CV, coefficient of variation; g, grams; mL, milliliters.

Table 2 – Moisture content of muffins

Sample	Dish (g)	Dish + Sample (g)	Dish + Dry Sample (g)	% MC	Average %MC	SD	CV
Commercial Muffin 1	1.2734	3.2785	2.7993	23.90			
Commercial Muffin 2	1.2604	3.2654	2.7837	24.02	23.9	0.07	0.3
Commercial Muffin 3	1.2642	3.2695	2.7903	23.90			
Control Muffin 1	1.2556	3.2530	2.7006	27.66			
Control Muffin 2	1.2667	3.2521	2.7070	27.46	27.5	0.13	0.5
Control Muffin 3	1.2561	3.3031	2.7417	27.43			
Whey Muffin (2X) 1	1.2541	3.3127	2.2358	52.31			
Whey Muffin (2X) 2	1.2596	3.2693	2.2167	52.38	52.4	0.05	0.1
Whey Muffin (2X) 3	1.2398	3.2361	2.1900	52.40			
Pea Muffin (2X) 1	1.2663	3.2743	2.1167	57.65			
Pea Muffin (2X) 2	1.2790	3.2829	2.1235	57.86	57.7	0.12	0.2
Pea Muffin (2X) 3	1.2625	3.2995	2.1252	57.65			
Whey Muffin (3X) 1	1.2592	3.2880	2.3311	47.17			
Whey Muffin (3X) 2	1.2575	3.2602	2.3206	46.92	47.1	0.13	0.3
Whey Muffin (3X) 3	1.2569	3.2668	2.3207	47.07			
Pea Muffin (3X) 1	1.2620	3.2970	2.0498	61.29			
Pea Muffin (3X) 2	1.2568	3.2597	2.0285	61.47	61.4	0.11	0.2
Pea Muffin (3X) 3	1.2613	3.2920	2.0435	61.48			

Abbreviations: 3X, triple protein; 2X, double protein; SD, standard deviation; CV, coefficient of variation; g, grams.

Table 3 – Color values of muffins

Sample	Value	Trial 1	Trial 2	Trial 3	Average	SD	CV
Commercial Muffin	L*	52.37	52.58	55.12	53.36	1.53	2.87
	a*	4.26	3.91	4.07	4.08	0.18	4.29
	b*	20.4	23.35	20.76	21.50	1.61	7.48
Control Muffin	L*	47.26	47.19	50.49	48.31	1.89	3.90
	a*	13.29	13.36	13.51	13.39	0.11	0.84
	b*	31.46	32.21	33.4	32.36	0.98	3.02
Whey Muffin (2X)	L*	41.88	42.05	41.81	41.91	0.12	0.29
	a*	16.13	15.24	15.80	15.72	0.45	2.86
	b*	28.74	28.36	28.32	28.47	0.23	0.81
Pea Muffin (2X)	L*	31.89	29.56	27.87	29.77	2.02	6.78
	a*	7.27	7.31	6.71	7.10	0.34	4.73
	b*	19.53	19.09	19.41	19.34	0.23	1.18
Whey Muffin (3X)	L*	40.92	38.42	38.12	39.15	1.54	3.93
	a*	18.73	17.3	17.69	17.91	0.74	4.13
	b*	21.71	22.22	22.27	22.07	0.31	1.40
Pea Muffin (3X)	L*	38.41	38.09	38	38.17	0.22	0.56
	a*	5.77	6.27	6.07	6.04	0.25	4.17
	b*	21.64	21.15	21.3	21.36	0.25	1.18

Abbreviations: 3X, triple protein; 2X, double protein; SD, standard deviation; CV, coefficient of variation; g, grams.

Table 4 – Texture analysis of muffins

Sample		Hardness (g)	Cohesiveness	Springiness	Gumminess (g)	Chewiness (g)
Commercial Muffin 1		529.89	0.57	0.90	299.63	268.74
Commercial Muffin 2		526.48	0.54	0.90	282.40	254.36
Commercial Muffin 3		531.02	0.54	0.98	286.32	279.99
	Average	529.13	0.55	0.93	289.45	267.70
	SD	2.37	0.02	0.05	9.03	12.85
	CV	0.45	2.93	4.94	3.12	4.80
Control Muffin 1		647.19	0.53	0.81	339.84	249.31
Control Muffin 2		621.08	0.53	0.75	329.17	245.45
Control Muffin 3		654.41	0.52	0.79	339.68	266.95
	Average	640.89	0.53	0.78	336.23	253.91
	SD	17.53	0.01	0.03	6.12	11.46
	CV	2.74	1.12	4.42	1.82	4.51
Whey Muffin (2X) 1		824.24	0.79	0.95	654.62	621.41
Whey Muffin (2X) 2		727.05	0.79	0.95	572.87	547.02
Whey Muffin (2X) 3		750.08	0.79	0.97	589.35	569.65
	Average	767.12	0.79	0.96	605.61	579.36
	SD	41.47	0.00	0.01	35.30	31.14
	CV	5.41	0.46	0.75	5.83	5.37
Pea Muffin (2X) 1		2204.30	0.53	0.75	1174.85	875.75
Pea Muffin (2X) 2		2204.68	0.52	0.75	1144.91	858.68

Pea Muffin (2X) 3		2264.80	0.53	0.71	1177.71	848.16
	Average	2224.59	0.53	0.74	1165.82	860.86
	SD	34.82	0.01	0.02	18.17	13.92
	CV	1.57	1.51	3.29	1.56	1.62
Whey Muffin (3X) 1		1750.48	0.63	0.94	1094.23	1026.68
Whey Muffin (3X) 2		1750.10	0.61	0.98	1062.20	1036.55
Whey Muffin (3X) 3		1707.27	0.67	0.94	1144.85	1074.76
	Average	1735.95	0.63	0.95	1100.43	1046.00
	SD	24.84	0.03	0.02	41.67	25.39
	CV	1.43	5.17	2.27	3.79	2.43
Pea Muffin (3X) 1		1283.16	0.42	0.62	617.51	419.35
Pea Muffin (3X) 2		1269.34	0.42	0.59	680.08	498.63
Pea Muffin (3X) 3		1235.81	0.42	0.54	651.98	433.00
	Average	1262.77	0.42	0.58	649.86	450.32
	SD	24.35	0.00	0.04	31.34	42.39
	CV	1.93	0.24	7.00	4.82	9.41

Abbreviations: 3X, triple protein; 2X, double protein; SD, standard deviation; CV, coefficient of variation; g, grams.

Table 5 – Nutrition content of muffin recipes, per serving (5 mini muffins per serving)

Sample	Calories	Carbohydrates (g)	Fat (g)	Protein (g)	Fiber (g)
Commercial	180	25	8	2	<1
Control	449	67	18	6	3
Whey 2X	267	43	3	20	8
Pea 2X	239	43	2	15	8
Whey 3X	315	44	4	28	8
Pea 3X	274	45	2	22	8

Abbreviations: 3X, triple protein; 2X, double protein; g, grams.

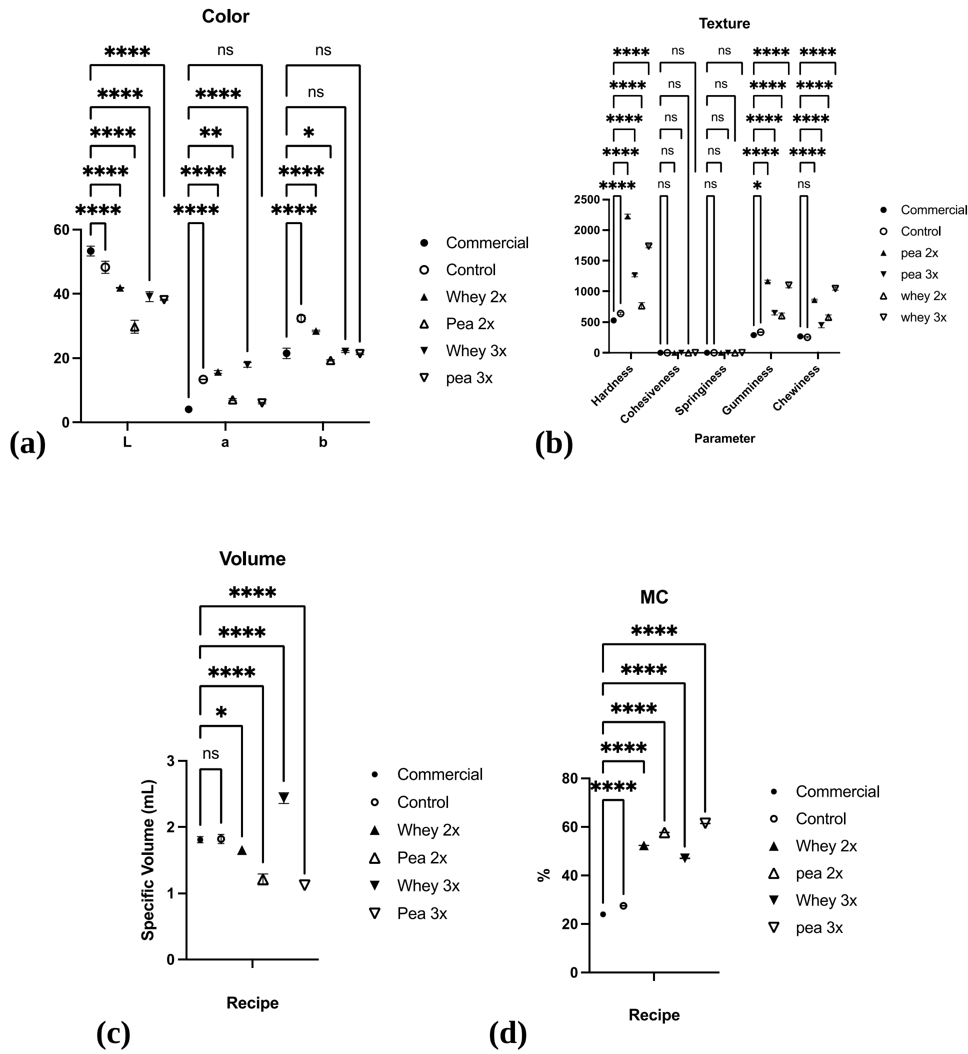
Table 6 – Ingredients for each muffin recipe

Sample	Ingredients
Commercial	Sugar, Bleached Wheat Flour, Soybean Oil, Blueberries, Eggs, Water, Glycerin, Modified Cornstarch, Whey, Natural Flavor, Salt, Leavening (Sodium Acid Pyrophosphate, Baking Soda, Monocalcium Phosphate), Mono- and Diglycerides, Potassium Sorbate (Preservative), Sorbitan Monostearate, Sodium Stearoyl Lactylate, Polysorbate 60, Xanthan Gum, Soy Lecithin, Cellulose Gum, Whey Protein Concentrate.
Control	• ½ cup, salted butter • 1.25 cup, sugar • 2 large, eggs • 1 tsp, vanilla extract • 2 tsp, baking powder • ½ cup, milk • 2 cups, blueberries • 1.125 cup oat flour
Whey 2X	• 3 medium, banana • 2 tbsp, sugar • 6 tbsp, almond milk • 1 tsp, vanilla extract • 1 tsp, cinnamon • 1.125 cup, oat flour • 1.5 tsp, baking powder • 1 tsp, baking soda • ½ cup, unsweetened applesauce • 8 tsp, inulin powder • 5 scoops, Impact vanilla whey protein powder
Pea 2X	• 3 medium, banana • 2 tbsp, sugar • 6 tbsp, almond milk • 1 tsp, vanilla extract • 1 tsp, cinnamon • 1.125 cup, oat flour • 1.5 tsp, baking powder • 1 tsp, baking soda

	• ½ cup, unsweetened applesauce • 8 tsp, inulin powder • 5 scoops, organic unflavored pea protein powder
Whey 3X	• 3 medium, banana • 2 tbsp, sugar • 8 tbsp, almond milk • 1 tsp, vanilla extract • 1 tsp, cinnamon • 1.125 cup, oat flour • 1.5 tsp, baking powder • 1 tsp, baking soda • ¾ cup, unsweetened applesauce • 8 tsp, inulin powder • 7.5 scoops, Impact vanilla whey protein powder
Pea 3X	• 3 medium, banana • 2 tbsp, sugar • 8 tbsp, almond milk • 1 tsp, vanilla extract • 1 tsp, cinnamon • 1.125 cup, oat flour • 1.5 tsp, baking powder • 1 tsp, baking soda • ¾ cup, unsweetened applesauce • 8 tsp, inulin powder • 7.5 scoops, organic unflavored pea protein powder

Preparation: Muffins were baked for 5 minutes at 425°F and then 15-20 minutes at 350°F. Abbreviations: 3X, triple protein; 2X, double protein.

Figure 1 – Significant differences of properties



Description: Significant differences are indicated by an asterisk. The more asterisks, the larger the significant difference.

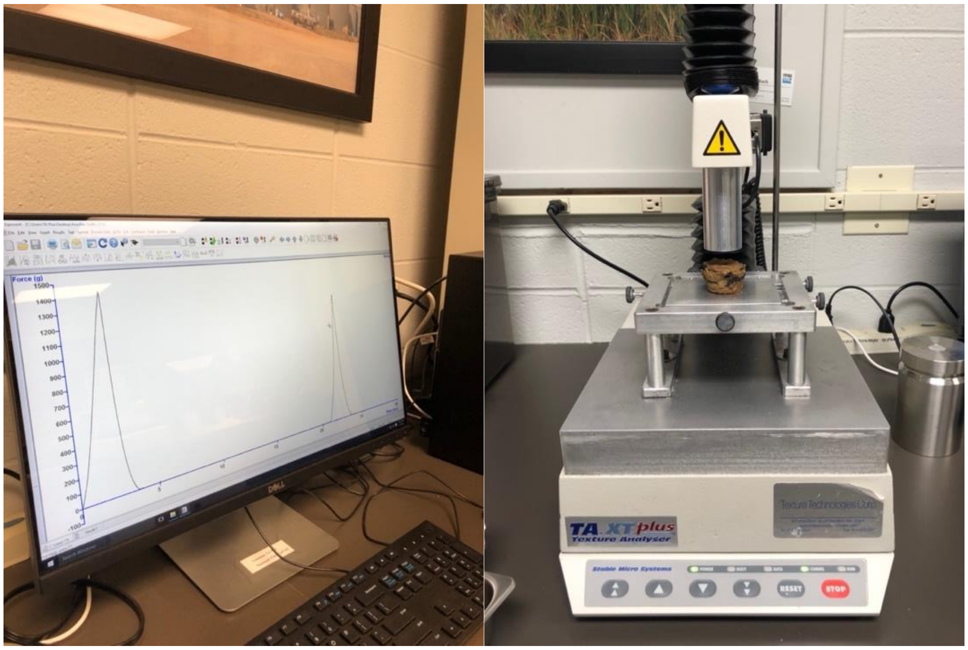
Figure 2 – Appearance of whey vs. pea protein muffins

Caption: The whey protein muffins (pictured left) and the pea protein muffins (pictured right) represent the recipes with double the protein content.

Figure 3 – Equipment and methods used for color measurements

Caption: The Chroma Meter used to measure the color of the crust of the various muffins.

Figure 4 – Equipment used for texture measurements



Caption: The program (pictured left) was used to export measurements from the TA.XT Plus texture analyzer (pictured right).

Figure 5 – Equipment and methods used for moisture content measurement

Caption: The whole muffins from each recipe (pictured top left) were ground into homogenous pastes (picture top right) before they were evenly distributed into aluminum pans (pictured bottom left) and dried out in the oven (pictured bottom right) to measure moisture content.

Figure 6 – Equipment and methods for specific volume measurement

Caption: The seeds (pictured left) were used along with a graduated cylinder (pictured right) to measure the displacement and calculate the specific volume of the muffins.

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