5-2018

The Effect of Breakfast on Energy Metabolism, Appetite, and Food Intake in Young versus Older Men

Allie Murphy
University of Arkansas, Fayetteville

The Effect of Breakfast on Energy Metabolism, Appetite, and Food Intake in Young versus Older Men

Allie Murphy

Spring 2018

Nutrition and Dietetics

Dale Bumpers College of Agricultural, Food, and Life Sciences

University of Arkansas

Acknowledgements

I would like to thank Dr. Jamie I. Baum for being my honors thesis mentor and her guidance and support of this project**.** I also give sincere thanks to Aubree Hawley for all of her assistance and contributions to the research project. Additionally I would like to thank the Food Science Department for allowing me to use their labs and facilities. I also would like to thank Dale Bumpers College of Agricultural, Food, and Life Science and the University of Arkansas Honors College for funding this research. Lastly, a special thank you to Mechelle Bailey and Dr. Laura Hill for serving on my thesis committee and their time and assistance throughout this process.

Table of contents

Abstract

As life expectancy continues to rise, it is important to consider optimal nutrition recommendations to improve health outcomes, quality of life, and physical independence in older adults. Previous studies have focused on the impact of breakfast on postprandial appetite in younger adults. Research on the effects of breakfast on appetite in older adults is limited. Several studies have identified protein as a key nutrient for older adults. Protein has been shown to increase satiety for longer periods of time and decrease cravings later in the day when compared to high carbohydrate meals. However, more research is needed to determine the influence of varying protein sources on appetite and satiety response, especially in older adults. The objective of this research was to determine the effect of protein density [(high quality, animal protein (e.g. whey protein) versus lower quality, plant protein (e.g. pea protein)] at breakfast on postprandial energy expenditure, appetite, and food intake in young and older men. This study was a randomized, crossover design. Eighteen men were recruited to participate in this study (n=12, younger men ages 18-29 years; n=6, older men (60 years of age and older). Participants received either a whey or pea protein breakfast beverage with a 1-2 week washout period between test days. Energy expenditure, appetite and blood values were measure for 240 minutes following the breakfast meal. At the conclusion of the test day, participants recorded their dietary intake via 24-hour food logs. There was no significant effect of diet or age on TEF, young men had a significantly higher TEF ($P < 0.01$) compared to older men following whey protein consumption. Pea protein decreased hunger and increased fullness following consumption. Both age and protein quality influenced appetite and energy expenditure following breakfast.

Introduction and Background

The maintenance of independence, quality of life, and health is critical in older adults. Aging is associated with a natural decline in muscle mass, strength, and physiological function, known as sarcopenia (Baum & Wolfe, 2015). After the age of 30, adults lose 3-8% of muscle mass per decade. Sarcopenia is highly prevalent in America as approximately 20% of adults less than 70 years old and more than 50% of those over 80 years of age can be characterized as sarcopenic (English & Paddon-Jones, 2010). A loss or reduction in skeletal muscle function often leads to increased morbidity and mortality either directly, or indirectly, via the development of secondary diseases such as type 2 diabetes, obesity and cardiovascular disease (Arthur & Cooley, 2012; Wolfe, 2012). The estimated direct healthcare cost attributable to sarcopenia in the United States in 2000 was $18.5 billion (Aging in Motion, 2018). Causes of sarcopenia include poor nutrition, diminished responsiveness to normal anabolic effect from hormones and/or nutrients, and a sedentary lifestyle (Kim, Wilson, & Lee, 2010). The functional limitations and impairments due to sarcopenia reduce quality of life and compromise functional independence as people age (Kim, Wilson, & Lee, 2010).

Changes in skeletal muscle mass are associated with additional physical changes that occur with aging (Baum & Wolfe, 2015). For example, body composition shifts with increased age resulting in higher percentages of body fat and a decrease in muscle mass, often without a change in body mass index (BMI) (Baum, Kim, & Wolft, 2016). This could be due to downregulation of the signaling mechanisms involved in protein synthesis. Signaling through mammalian target of rapamycin complex 1 (mTORC1) is involved in the regulation of several anabolic processes in the body including the process of muscle protein synthesis (MPS). Signals provided by the essential amino acids (EAA), especially the branched-chain amino acid (BCAA)

leucine, are required for full activation of this pathway. With increasing age, older adults become resistant to normal stimulatory effects of postprandial leucine, which may result in the reduced stimulation of mTOR1C and attenuation in skeletal protein synthesis (Baum, Kim, & Wolfe, 2016). Total energy expenditure (TEE) also decreases with age due to decreases in resting metabolic rate (RMR) concurrent with decreases in skeletal muscle mass and decreased physical activity (Manini, 2010).

Protein intake greater than the amount needed to avoid negative nitrogen balance may prevent sarcopenia and maintain energy balance (Baum & Wolfe, 2015). Increased protein intake at meals increases the thermic effect of food (TEF). The TEF is related to the amount of energy required to digest and process foods in the postprandial period. It contributes to an increase of postprandial energy expenditure above baseline and is influenced by the macronutrient composition of the diet (Baum, Gray, & Binns, 2015). Reported TEF values are a 0 to 3% increase for fats, a 5-10% increase for carbohydrates, and a 20-30% increase for proteins (Veldhorst, Smeets, et al., 2008). This effect may be larger for proteins because they are metabolized immediately since they cannot be stored in the body (Blom, et al., 2006). Furthermore, whey protein (an animal protein source) has been shown to elicit a greater thermogenic response than proteins such as soy or casein (a plant protein source) (Jakubowicz & Froy, 2013). The high leucine content in whey protein may be related to its ability to stimulate MPS, which may account for its thermogenic effect (Jakubowicz & Froy, 2013).

Protein quality has traditionally been defined by amino acid composition, as measured by an essential amino acid score or by the ratio of essential to nonessential nitrogen (Bauer, 2013). The rate and digestibility is determined by the amino acid profile of the protein. Different sources of protein have different EAA profiles and induce different responses of orexigenic

hormones (Pesta & Samuel, 2014) Proteins with higher leucine, lysine, tryptophan, isoleucine, and threonine content decreased hunger rates after ingestion (Pesta & Samuel, 2014). In general, meat-based foods contain higher amounts of EAAs than vegetable-based foods (Kim, Wilson, & Lee, 2010). Whey protein is a fast digesting protein that results in a robust anabolic effect. This means that it passes quickly through the stomach and remains intact because it is soluble. This leads to increased levels of leucine and other BCAAs, and stimulates mTORC1 signaling and activation leading to protein synthesis and augmented postprandial thermogenesis.

Timing of protein ingestion is an additional factor to consider. Breakfast is often thought to be the most important meal of the day and has been previously associated with a lower BMI (Deshmukh-Taskar, Nicklas, Radcliffe, O'Neil & Liu, 2012). On the contrary, skipping breakfast has been associated with increased risk of weight gain and obesity in young adults (Timlin & Pereira, 2008). This suggests that breakfast omission either leads to an increase in energy intake or a reduction in energy expenditure throughout the day, resulting in a state of positive energy balance promoting weight gain (Clayton & James, 2015). Recent data suggests that increasing protein intake at breakfast increases energy expenditure and improves muscle function throughout the day (Jakubowicz & Froy, 2013).

Consuming protein at breakfast may also increase feelings of fullness and satiety. Satiety can be influenced by a wide variety of factors including palatability, food mass, energy density, fiber, and glycemic index (Halton & Hu, 2004). Increased concentrations of amino acids contribute to satiety through stimulation of gluconeogenesis, and preventing a decrease in glycemia (Velderhost, Smeets, et al., 2008). An additional physiological process in which proteins induce satiety occurs via stimulation of the anorexigenic gut peptides cholecystokinin

(CCK) and glucagon like peptide 1 (GLP-1) (Blom, et al., 2006). CCK and GLP-1 secretion enhances satiety and decreases gastric emptying.

The Recommended Dietary Allowance (RDA) recommends consuming 0.8 g/kg/d of protein for all healthy men and woman over the age of 18 (USDA, 2010). This amount is based on the minimum dietary protein required to achieve nitrogen balance (Layman et al., 2015). Most adults consume a majority of protein (38g) at dinner, and 13 grams at breakfast (Baum &Wolfe, 2015). When comparing participants who consume protein equally versus unequally (meaning 60% of daily protein intake at dinner), the group who consumed protein equally spaced throughout the day had increased stimulation of 24-hour protein synthesis (Mamerow et al., 2014). Meals containing less than 30 g of protein attenuate postprandial MPS. This dose-dependent response may be deleterious for older adults experiencing anabolic resistance, or an exaggerated reduction in MPS in response to meals with a lower protein content (Mamerow, et al., 2014).

Further research is needed to determine how protein density (amount of essential amino acids per gram of protein) at breakfast influences food intake and appetite throughout the day. Therefore, the objective of this study was to determine the effect of protein density [(high quality, animal protein (e.g. whey protein) versus lower quality, plant protein (e.g. pea protein)] at breakfast on postprandial energy expenditure, appetite, and food intake in young and older men. We hypothesized that a breakfast with a higher protein density would decrease postprandial appetite and food intake in men and increase postprandial energy expenditure when compared to a breakfast with a lower protein density.

Materials & Methods

Subject Recruitment and Participation: Participants were recruited via advertisements in the University of Arkansas Newswire, in the local newspaper, social media (e.g. Facebook), flyers in the community, and word of mouth. Young men (18-29 years of age) and older men (60 years of age or greater) were recruited to participate in this study. Participants who had food allergies, diet restrictions, did not habitually eat breakfast, were picky eaters or had any other diet-related conditions that would prevent them from consuming whey or pea protein supplements were excluded from the study. Participants who implemented strenuous physical activity for more than 4 hours per week or were currently dieting were also excluded from the study. In order to participate in the study, participants were required to undergo a phone screening to determine if they met the minimum study qualifications. This study was approved by the Institutional Review Board (IRB) and all participants signed an informed consent to participate. The current study is registered under the University of Arkansas IRB as ID #1708022784.It is also registered as a clinical trial as ID # NCT03399812.

Study Design: A total of 18 participants, 12 young and 6 older men, were recruited to participate in the (randomized cross over design) study. Over the 3-week period, each participant was required to visit the Nutrition and Energy Metabolism Laboratory at the Food Science building at the University of Arkansas on two occasions. Participants underwent two separate treatments with a 1 to 2 week washout period between treatments. The second treatment began 1 to 2 weeks following the first treatment day. The two treatments included a whey-based drink containing 40 grams of protein and a pea-based drink containing 40 grams of protein (refer to **Table 1** and **Table 2** for compositions of each test drink). Protein treatments were made in a shaker bottle following the corresponding recipe.

The night before each site visit, participants were instructed to fast overnight (10-12 hours) and refrain from strenuous physical activity the day before testing. Upon arrival, participants underwent baseline assessment of anthropometrics (weight and height) and had an intravenous catheter (I.V.) inserted into the non-dominant arm. Following the I.V. insertion, a blood draw was collected, baseline appetite values were recorded using visual analog scales (VAS), and resting energy expenditure (REE) was measured using a metabolic cart. Subsequently, each drink was administered in an opaque serving container and consumed through a straw within 10 minutes. Participants were asked a series of questions regarding appetite and taste on a visual analog scale at 0, 15, 30, 60, 90, 120, 180, and 240 minutes. REE was measured at 0, 30, 60, 120, 180, and 240 minutes. Blood was collected at 0, 30, 60, 90, 120, and 240 minutes. At the conclusion of the test, each participant was instructed to keep a detailed 24-hour food log for the remaining 24-hours.

Table 1. Nutrient compositions of each protein drink treatments

Drink Type	**Whey**	**Pea**
Kcal	265.819	263.819
Protein (g)	40.00	40.00
CHO (g)	15.00	15.00
Fat (g)	4.375	4.17
Fiber (g)	3.60	3.33

Table 2. Recipe for protein drink treatments

Drink Type	**Whey**	**Pea**
Water added (mL)	350 mL	350 mL
Protein powder added (g)	50	73.33
Cane Sugar added (g)	13	-
Canola Oil added (tsp)	0.75	-
Inulin added (g)	1.6	-

Measurements & Data Analysis

Body Composition, Height and Weight: Weight and height were measured before each dietary intervention. Body composition was determined after the two test days were complete via DXA (dual energy x-ray absorptiometry) analysis.

Dietary Assessment: Participants were asked to record their 24-hour food intake on each treatment day. Each participant provided two 24-hour food logs. The energy and macronutrient composition of test breakfast drinks and 24-hour dietary records were analyzed using Genesis R&D analysis software package (Salem, OR).

Appetite Assessment: A VAS (Visual Analogue Scale) spanning 100-mm with opposing anchors (e.g. "extremely hungry" to "not hungry at all") was utilized to periodically assess perceived hunger, fullness, strength of desire to eat, desire for a snack, amount of prospective food desired, cravings for salty foods, and cravings for sweet foods at 0, 15, 30, 60, 90, 120, 180, and 240 minutes postprandial. Palatability was assessed at 15 minutes after the drink was consumed.

***Energy Expenditure (EE)*:** REE (Resting Energy Expenditure) and TEF (Thermic Effect of Food) were measured with a TrueOne 2400 metabolic cart (Parvomedics, Sandy, UT). Indirect calorimetry was measured using the ventilation hood technique. A canopy hood was placed over each participant's head and breath-by-breath analysis was conducted throughout a four-hour period at 0, 30, 60, 120, 180, and 240 minutes postprandial. The REE and TEF values were used to calculate various components of whole body energy metabolism.

Biomarkers of Energy Metabolism: Blood samples were collected on two separate occasions (each treatment) via intravenous puncture by a trained phlebotomist. Each blood draw was collected via a butterfly needle with a catheter or through individual sticks with vacutainer

attachment. Blood was collected at 0, 30, 60, 90, 120, and 240 minutes postprandial. Participants had the option to choose individual sticks over the administration of an I.V. catheter.

Statistical Analysis: Repeated measures Analysis of Variance (ANOVA), two-way ANOVA, and t-test were used to determine differences in food intake and energy metabolism in young and older men based on protein source at breakfast (whey based protein drink vs. pea based protein drink).

Results

Participant Characteristics

A total of 18 men were enrolled in the study. **Table 3** contains participant demographics and baseline anthropometric measurements.

Table 3. Participant Characteristics

Characteristics	Young	Older
Participants	12	6
Age	25 ± 2.7	65 ± 3.5
Height (m)	1.76 ±. 07	1.79 ±. 06
Weight (kg)	77.3 ± 10.1	87.1 ± 12.9
BMI	25.0 ± 3.0	27.3 ± 3.3
Ethnicity		
Asian American	2	0
Caucasian	9	5
Asian	1	0

Dietary Assessment

Food intake over the 24 hours following each study day was collected and analyzed using Genesis R&D software. Total caloric intake and the amounts of each macronutrient in grams of carbohydrate, fat, or protein following each treatment is shown in **Table 4.** Both young and older men consumed fewer calories throughout the day after the pea protein shake compared to the whey protein shake. Young and older men consumed an average of 323 kcal and 606 kcal less

respectively. Older men consumed significantly less kcal ($P < 0.05$) after consumption of pea protein shown in **Figure 1**. Older men consumed fewer carbohydrates following consumption of the pea shake ($P=0.06$). (**Figure 2**). No significant difference in protein intake shown in **Figure 3**. Protein displayed as grams eaten was slightly higher after the whey protein shown in **Table 4**. There was no significant difference in fat intake between groups shown in **Figure 4.** Intake of sodium, fiber, and sugar also showed no significant different among groups as shown in **Figure 5, 6,** and **7**.

Calories consumed as snacks in the afternoon (PM) versus before bed (HS) were also compared in both groups. Young men consumed more calories after both protein shakes PM and older men consumed more calories after both protein shakes HS shown in **Figure 8A** and **8B**.

Table 4. Summary of 24-hour food intake following either whey or pea protein intake at breakfast

	Whey Young	**Pea Young**	**Whey Older**	**Pea Older**
Kcal	2405±805	2082±518	2462±363	1856±408
CHO (g)	**237±81**	**234±88**	**244±90**	**157±44**
% kcal from CHO	42%	36%	43%	34%
Protein (g)	**127±44**	**123±31**	**138±29**	**118±22**
% kcal from Protein	22%	24%	24%	25%
Fat (g)	**83±40**	**73±33**	**99±24**	**74±28**
% kcal from Fat	33%	32%	33%	36%
Fiber (g)	**24±11**	**26±13**	**21±6**	**18±7**

Figure 1

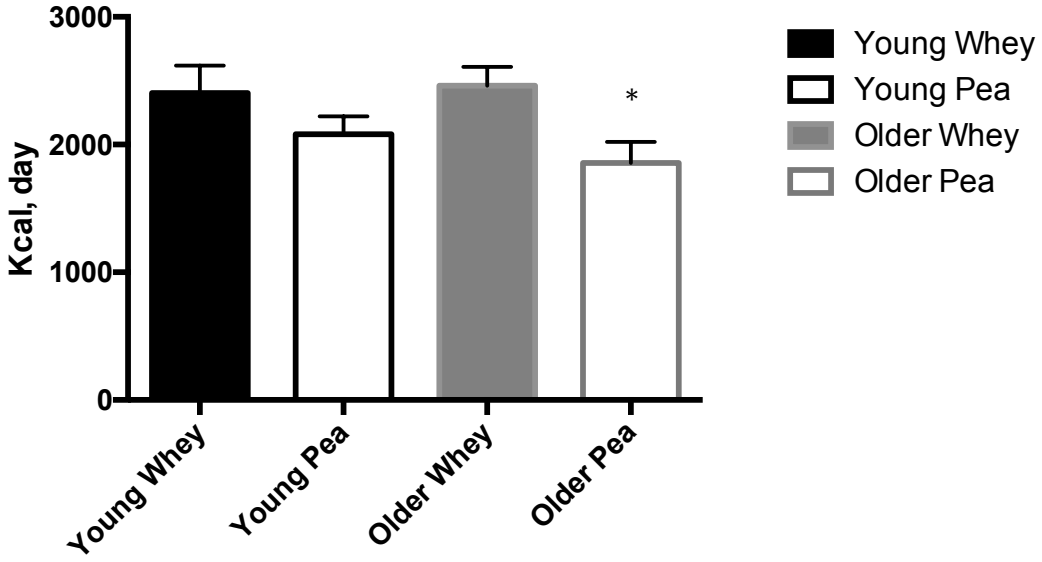

Figure 1: The effect of protein source and age on 24-hour calorie intake. Data expressed as means ± SEM.

Figure 2

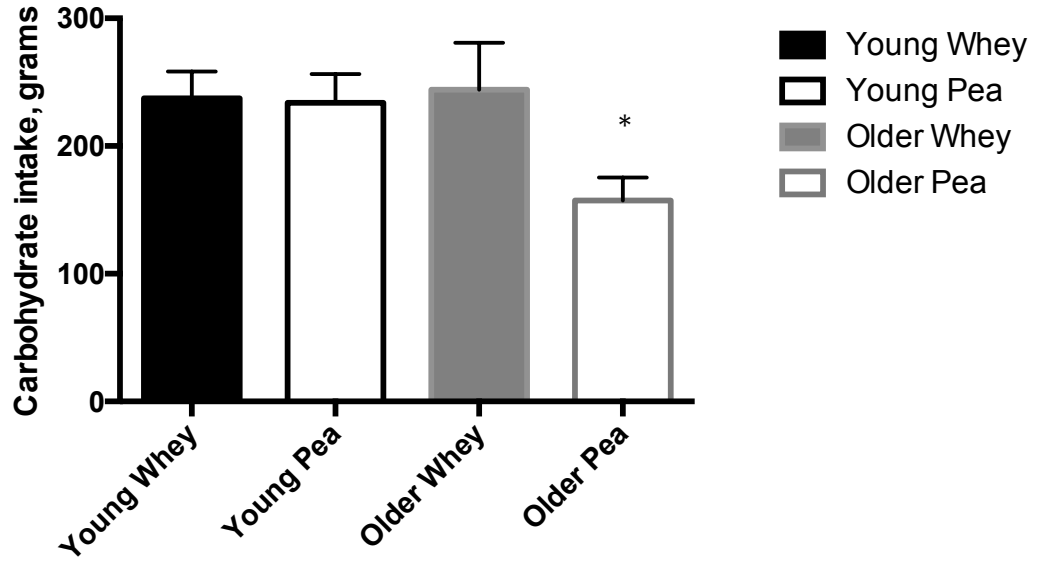

Figure 2: Average consumption of carbohydrates in the 24-hour period following each protein treatment. Data expressed as means ± SEM.

Figure 3

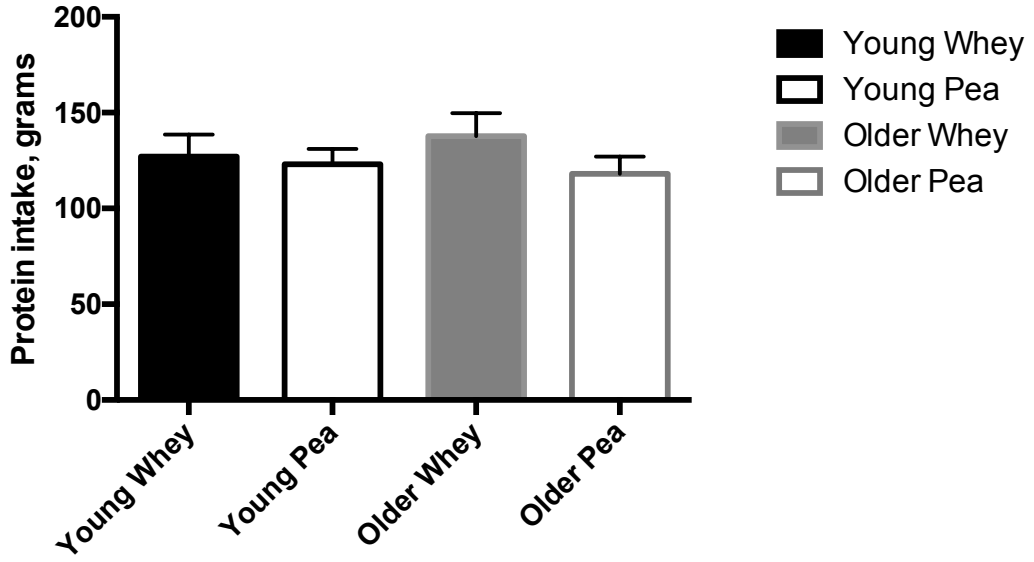

Figure 3: Average consumption of protein consumed in the 24-hour period following each protein treatment. Data expressed as means ± SEM.

Figure 4

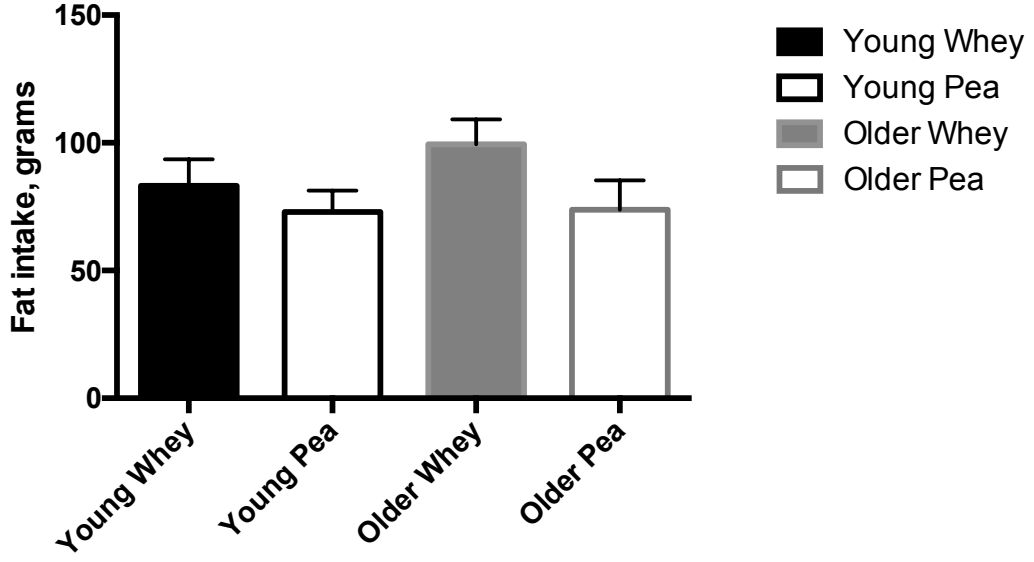

Figure 4: Average consumption of fat consumed in the 24-hour period following each protein treatment. Data expressed as means ± SEM.

Figure 5

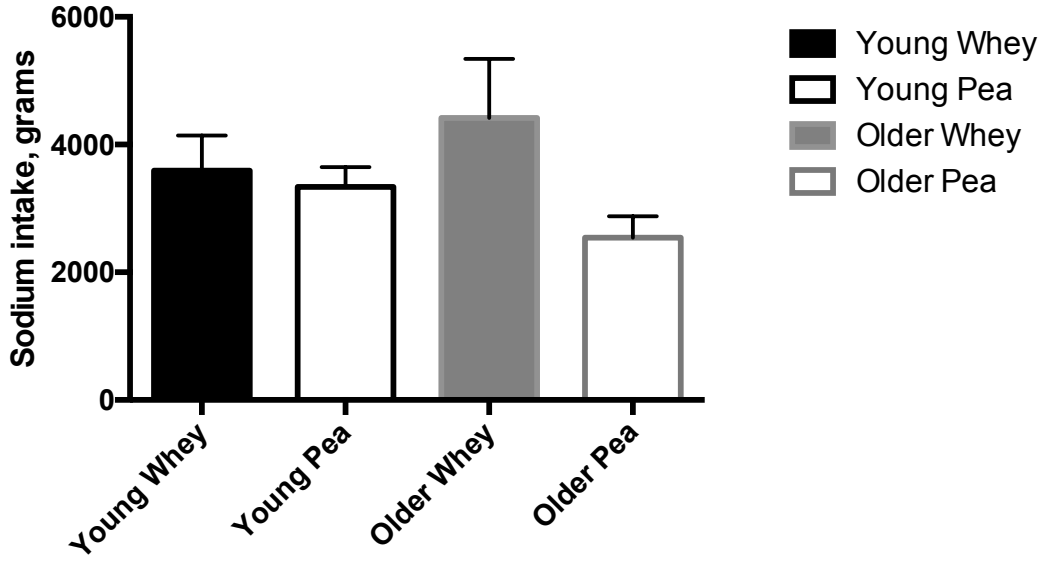

Figure 5: Average consumption of sodium consumed in the 24-hour period following each protein treatment. Data expressed as means ± SEM.

Figure 6

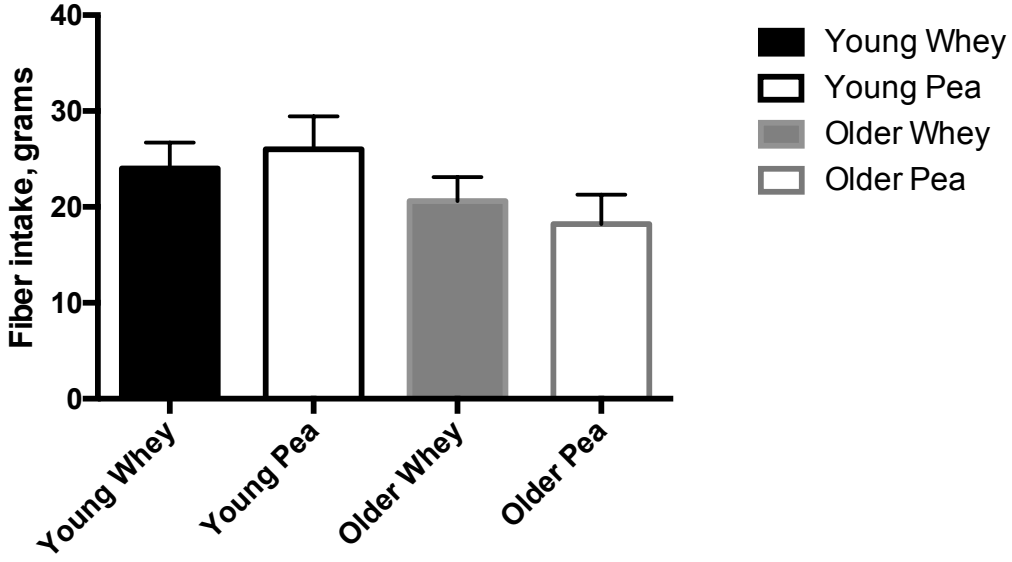

Figure 6: Average consumption of fiber consumed in the 24-hour period following each protein treatment. Data expressed as means ± SEM.

Figure 7

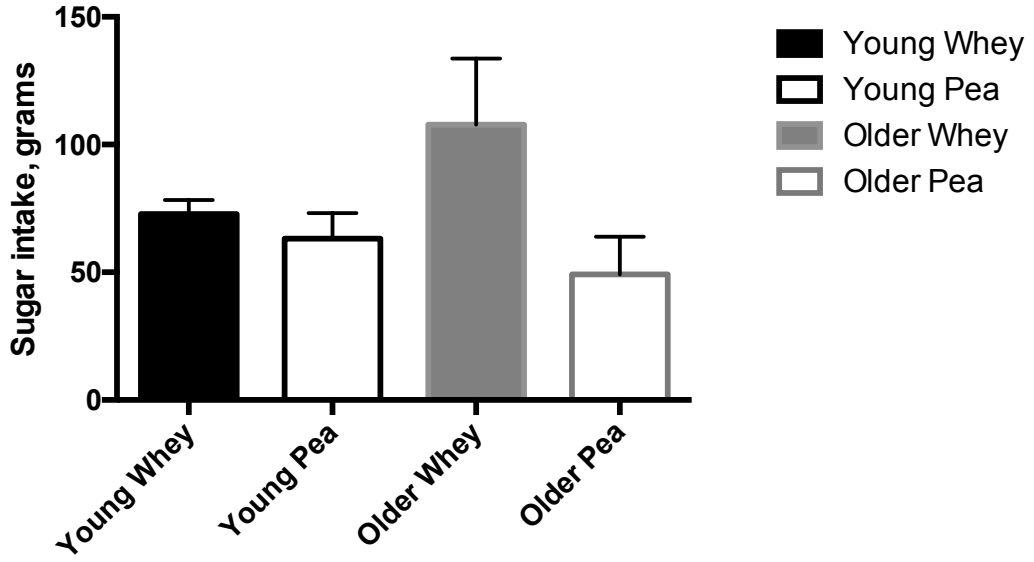

Figure 7: Average consumption of sugar consumed in the 24-hour period following each protein treatment. Data expressed as means ± SEM.

Figure 8A

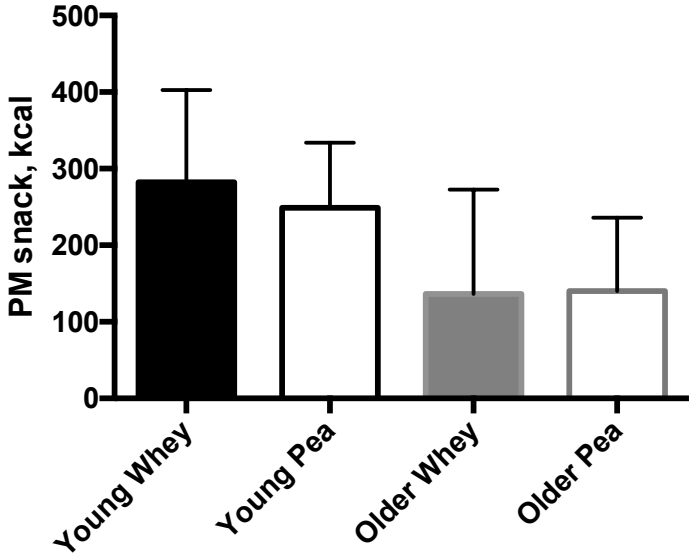

Figure 8A: Average amount of kcal consumed in the afternoon (PM) following each protein treatment. Data expressed as means ± SEM.

Figure 8B

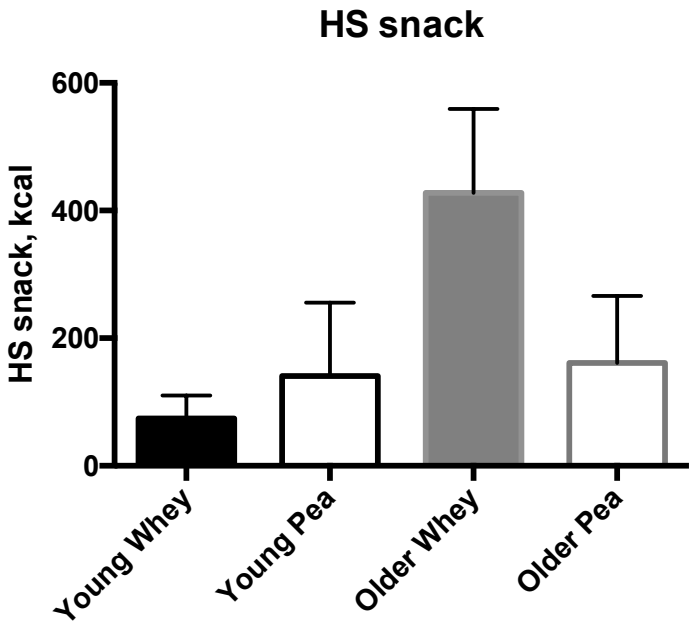

Figure 8B: Average amount of kcal consumed before bed (HS) following each protein treatment. Data expressed as means ± SEM.

Appetite Assessments

Perceived Hunger and Fullness:

The perceived hunger and fullness of the participants measured by VAS scale at 0, 15, 30, 60, 90, 120, 180 and 240 minutes postprandial for each protein drink was assessed and is shown in **Figure 9** and **Figure 10.** Hunger increased over time after consumption of both shakes in both groups while fullness decreased over time. A two-way ANOVA showed that there was a significant effect of time ($P < 0.001$) and diet ($P= 0.001$) on hunger response. Young men were significantly hungrier following whey protein ($P < 0.01$) and older men were significantly hungrier following whey ($P< 0.05$). A two-way ANOVA showed there was significant effect on time ($P< 0.0001$) and diet ($P< 0.0001$) on feelings of fullness. Young men were significantly more full following pea protein ($P < 0.001$) and older men were significantly more full following pea protein ($P <0.05$).

Figure 9

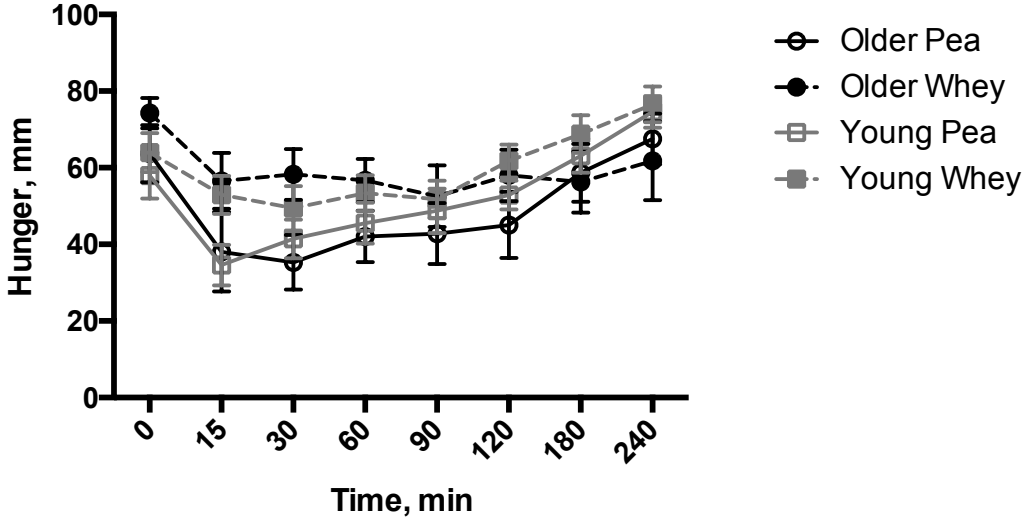

Figure 9: Hunger response in young versus older men following whey or pea protein ingestion at breakfast. Data expressed as means ± SEM

Figure 10

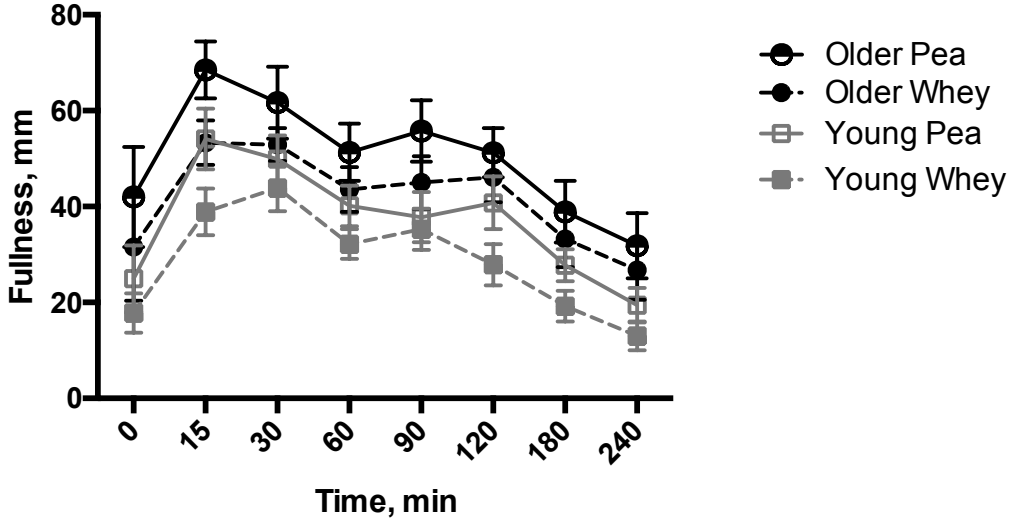

Figure 10: Fullness response in young versus older men following whey or pea protein ingestion at breakfast. Data expressed as means ± SEM.

Strength of desire to eat and prospective food consumption:

The prospective amount of food desired, perceived strength of desire to eat, desire for a snack was assessed using a VAS at 0, 15, 30, 60, 90, 120, 180, and 240 minutes post prandial (**Figure 11, Figure 12,** and **Figure 13).** There was a significant effect of time ($P < 0.0001$) and diet ($P < 0.0001$) on prospective food consumption and desire to eat. Younger men had significantly lower prospective food consumption ($P < 0.01$) and desire to eat ($P < 0.001$) following pea protein. Older men had significantly lower prospective food consumption and desire to eat ($P < 0.05$) following pea protein. There was No significant effect of time ($P < 0.0001$), diet ($P < 0.0001$), and age ($P < 0.001$) on desire for a snack. Younger men had significantly lower desire for a snack compared to older men ($P < 0.0001$). All participants had significantly higher desire for a snack following whey protein treatment($P < 0.001$).

Figure 11

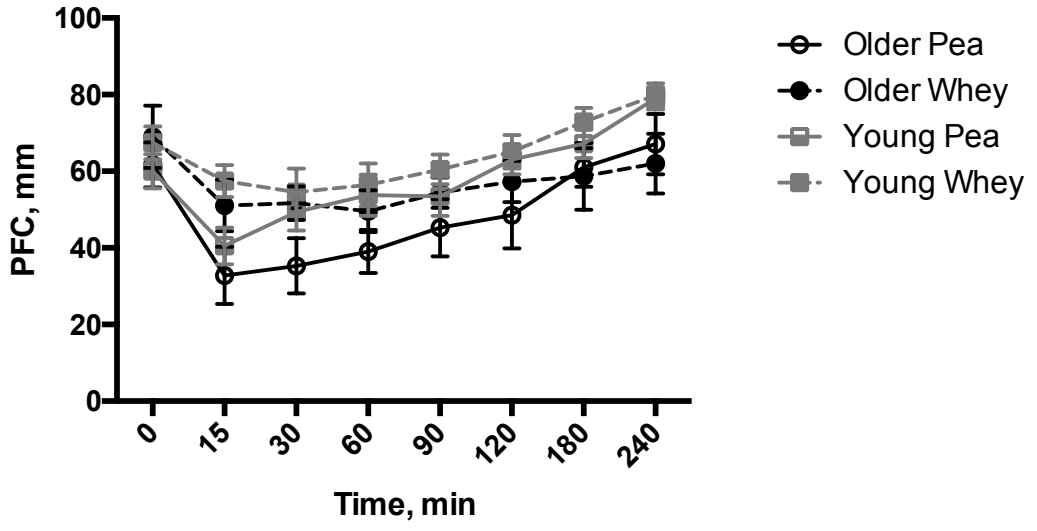

Figure 11: Prospective amount of food consumption in young versus older men following whey or pea protein ingestion at breakfast. Data expressed as means $\pm$ SEM.

Figure 12

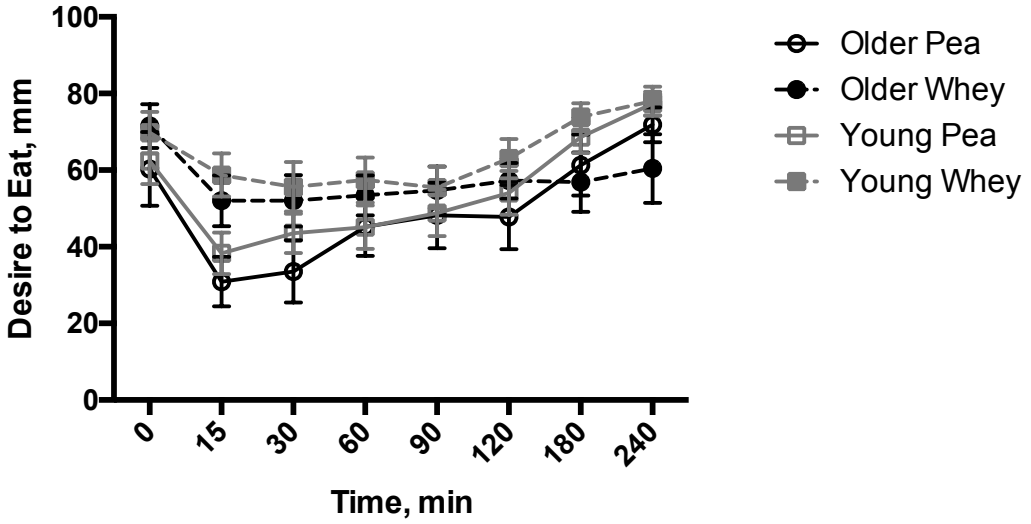

Figure 12: The perceived desire to eat in young versus older men following whey or pea protein ingestion at breakfast. Data expressed as means ± SEM.

Figure 13

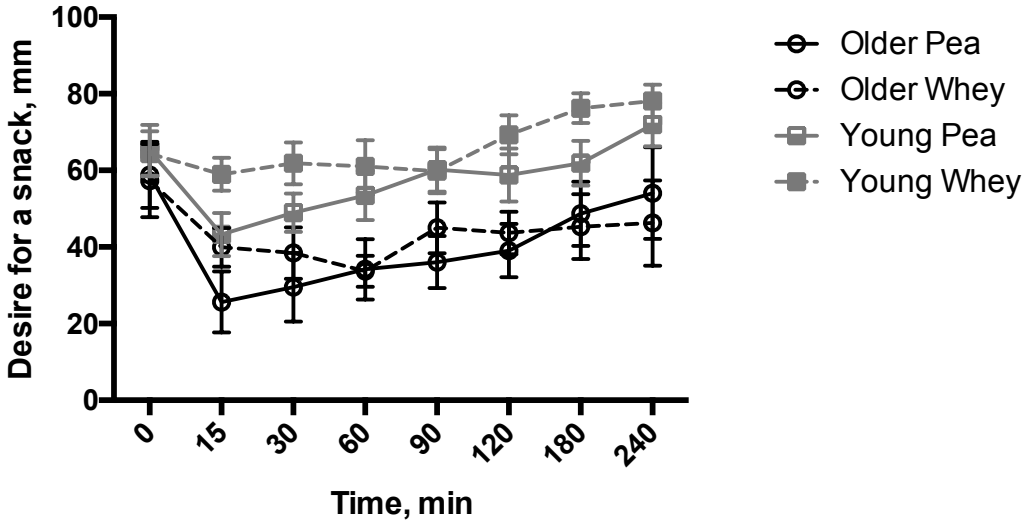

Figure 13: The perceived desire for a snack in young versus older men following whey or pea protein ingestion at breakfast. Data expressed as means ± SEM.

Perceived salty/sweet cravings:

The perceived cravings for sweet and salty foods by the participants measured by VAS scale at 0, 15, 30, 60, 90, 120, 180 and 240 minutes postprandial for each protein drink was assessed (**Figure 14** and **Figure 15).** There was no effect of age, diet or time on sweet cravings. There was a significant effect of age ($P < 0.0001$) on craving for salty foods. Younger men had higher craving for salty foods compared to older men ($P < 0.0001$). There was no effect of protein source on craving for salty foods.

Figure 14

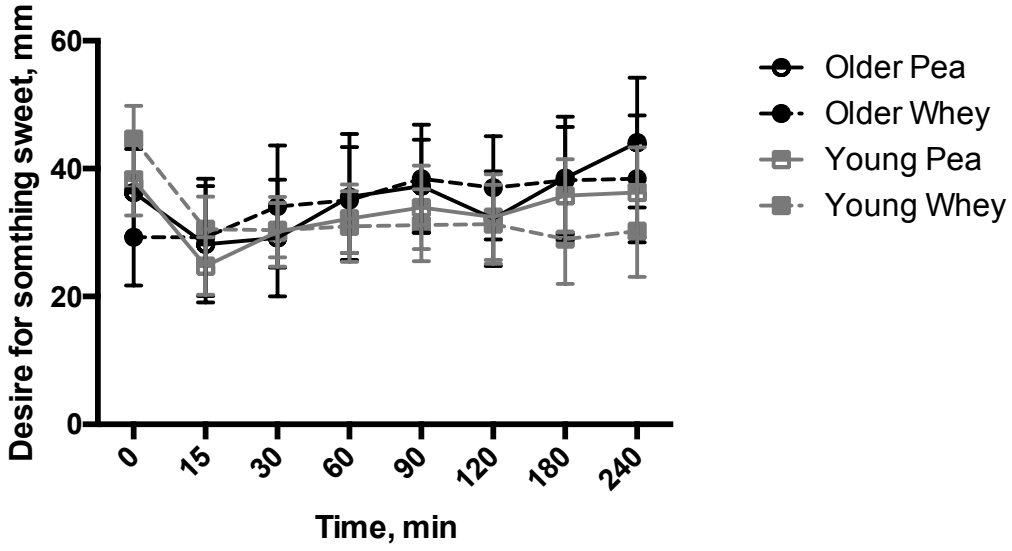

Figure 14: The perceived desire for sweet intake in young versus older men following whey or pea protein ingestion at breakfast. Data expressed as means ± SEM.

Figure 15

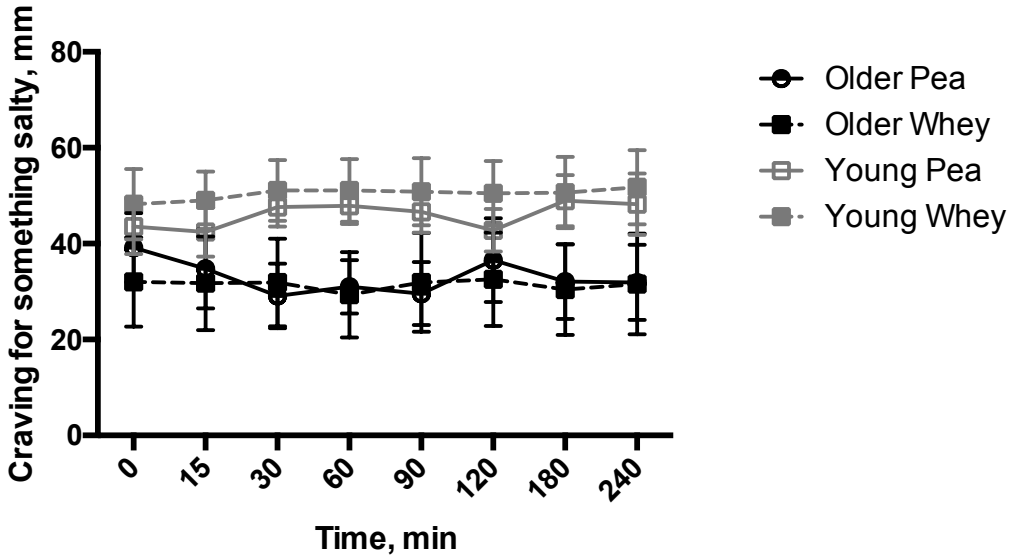

Figure 15: The perceived desire for salty food in young versus older men following whey or pea protein ingestion at breakfast. Data expressed as means ± SEM.

Taste Preferences

Taste was assessed on a VAS scale at 15 minutes after the consumption of the each intervention drink and is shown in **Figure 16.** Both younger and older men preferred the whey beverage ($P < 0.01$).

Figure 16

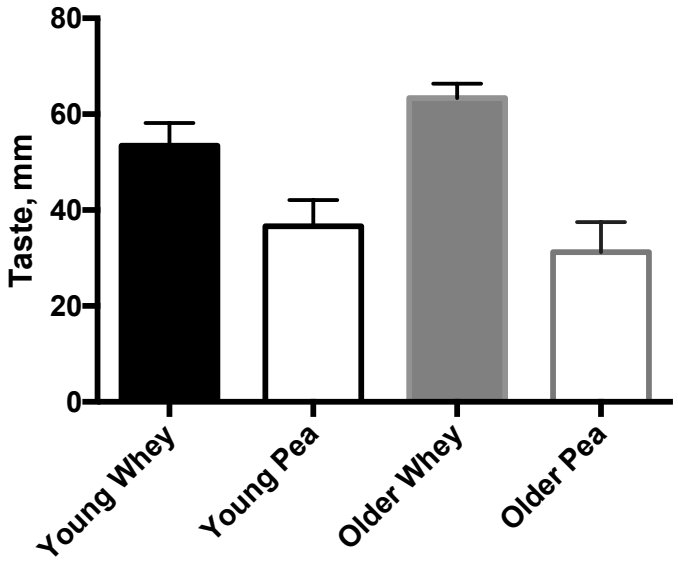

Figure 16: Taste preferences in young versus older men after following ingestion of the whey or pea protein at breakfast. Data expressed as means ± SEM.

Metabolic Measurements

TEF:

The thermic effect of food (TEF) was calculated from the REE at 0, 30, 60, 90, 120, 180, and 240 minutes postprandial as shown in **Figure 17.**

Results from a two-way ANOVA showed no significant effect of diet or age on TEF. However, there was a significant effect of time ($P<0.001$). Young men had significantly higher TEF ($P<0.01$) compared to older men following whey protein treatment. Older men following the whey protein treatment had higher energy expenditure than older men who consumed pea. The TEF was always lower in older men than in younger men.

Figure 17

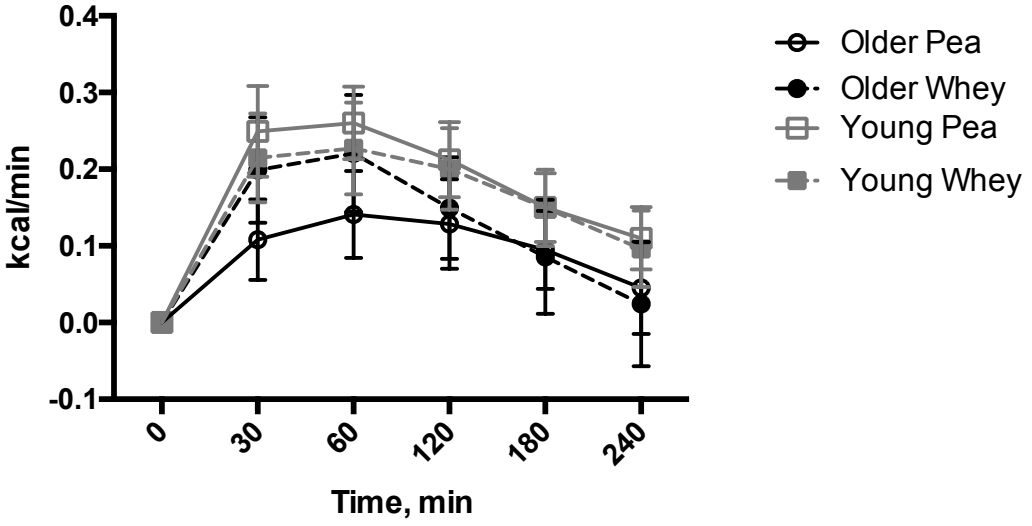

Figure 17: Results from the Thermic Effect of Feeding (TEF) averaged over time using a Two-Way ANOVA. Data expressed as means $\pm$ SEM.

Discussion:

This is one of the first studies to compare protein quality at breakfast on appetite and energy metabolism in young versus older men. This study compared two different sources of protein that were matched in macronutrient, calories, and volume. The various effects on satiety, appetite, TEF, and food intake were analyzed for the remainder of the day in young and older men. Based on current research, the hypothesis was that the higher quality protein (whey protein) would have a greater metabolic effect and decrease appetite and food intake throughout the day when compared to the lower quality protein (pea protein). Results from this study indicated that all participants had decreased appetite and food intake throughout the day following pea protein consumption compared to whey protein. Older adults had higher TEF following whey protein compared to pea protein.

Protein source may be an important factor with connections between both the physiological and hormonal postprandial meal response. Several studies have looked at protein-induced satiety (Anderson & Moore, 2004; Velderhost et al., 2008; and Pesta & Samuel, 2014) and support the results from this study. Prospective food consumption, desire to eat, and desire for a snack were lower following pea protein intake in both young and older men. Age might also play a role; older men had higher cravings for salty foods following both protein treatments, as well as greater desire for a snack. Recent research from Pesta & Samuel (2014) showed that pea protein hydrolysate was most effective in suppressing hunger followed by whey as compared to milk protein. This study supported that both younger and older men were significantly hungrier following the whey protein treatment compared to the pea protein treatment.

Previous studies have also compared amount of protein consumed as an important factor in influencing satiating hormones. Protein consumption greater than 30 grams has shown to be

more satiating than consumption of 20 grams (Layman et al., 2015). Both protein treatments in this study contained 40 grams of protein, which could have had more of an impact on the satiating effects than the amino acid composition. Typically plant proteins are limited in one or more essential amino acids (Layman et al., 2008), however, the pea protein that was used in the study contained all of the essential and non-essential amino acids in small quantities.

Despite dietary intake being similar among all groups following each different treatment, older men consumed significantly fewer calories following the pea protein treatment. There was no significant difference found in protein, fat, sodium, fiber, or sugar consumption following each treatment. Previous research identifies protein as being important at breakfast for reducing calories and found no significant difference in the source of protein (Timlin & Pereira, 2008). Additional research conducted by Leidy et al. (2008) compared macronutrient composition at breakfast to hunger and food intake through out the day. Results showed that the high protein breakfast decreased food intake and hunger throughout the day compared to a low protein high carbohydrate breakfast. Previous research also found that breakfast consumption leads to decreased snacking though out the day; compared to skipping breakfast which increased high fat snacks consumption (Leidy et al., 2008). No significant difference in calories consumed as a snack throughout the day in the current study.

No significant difference in cravings for sweet and salty foods were found among the protein treatments; however, young men had a higher craving for salty foods compared to older men. Future research may determine if taste of the treatment beverage affects these cravings since there was no difference seen between protein treatments.

Young men had a significantly higher TEF compared to older men following whey and pea protein consumption. Older men had a higher TEF following whey consumption than pea.

Previous research identified a decrease in RMR with age (Manini, 2009). This is due to a decrease in protein synthesis that occurs. Previous research by Jakubowicz & Froy, 2008 found that the high leucine content in whey protein may be related to its ability to stimulate muscle protein synthesis, which may account for its thermogenic effect. The leucine content was higher in the whey protein used in this study, (5.0 grams, compared to 3.35 grams in the pea protein).

Limitations of the study include the small sample size in the older population (n=6). This study was still ongoing so limited data was available due to time constraints. This study only had 2 study days (1 for each treatment) to compare food intake. Increased study days would allow for possible trends in postprandial food consumption to be seen. Also, food records may be inaccurate due to self-assessing abilities. When matching the different protein drinks, only the macronutrient composition and total volume was matched. Viscosity was not taken into account and the pea protein shake was much thicker. This could have affected the satiety responses and increased the feelings of fullness seen among participants.

In conclusion, pea protein decreased hunger and increased fullness when compared to whey protein. No statistical differences were seen in macronutrients consumed following each treatment drink. This suggests that protein source does not affect the amount of calories consumed each day. Longer term research with a larger sample size should determine the statistical differences of varying protein sources on satiety, postprandial food consumption, and TEF in younger and older men.

References

Aging in motion (2018). *The facts about sarcopenia*. Retrieved from http://www.aginginmotion.org/wp-content/uploads/2011/04/sarcopenia_fact_sheet.pdf

Arthur, S. & Cooley, I. (2012). The effect of physiological stimuli on sarcopenia; impact of notch and wnt signaling on impaired aged skeletal muscle repair. *International Journal Of Biological Sciences*, *8*(5), 731-760. http://dx.doi.org/10.7150/ijbs.4262

Anderson, G. & Moore, S. (2004). Dietary proteins in the regulation of food intake and body weight in humans. [online] Jn.nutrition.org. Available at: http://jn.nutrition.org/content/134/4/974S.full

Balentine, J. (2017). Obesity: Get the facts on guidelines and statistics. MedicineNet. Available at: https://www.medicinenet.com/obesity_weight_loss/article.htm

Baum, J., Gray, M. and Binns, A. (2015). Breakfasts higher in protein increase postprandial energy expenditure, increase fat oxidation, and reduce hunger in overweight children from 8 to 12 Years of Age. *Journal of Nutrition*, 145(10), pp.2229-2235.

Baum, J. and Wolfe, R. (2015). The link between dietary protein intake, skeletal muscle function and health in older adults. *Healthcare*, 3(3), pp.529-543.

Blom, W. A., Lluch, A., Stafleu, A., Vinoy, S., Holst, J. J., Schaafsma, G., & Hendriks, H. F. (2006). Effect of a high-protein breakfast on the postprandial ghrelin response. *The American Journal of Clinical Nutrition*, 83(2), 211-220.

Cdc.gov. (2017). Adult Obesity Facts | Overweight & Obesity | CDC. [online] Available at: https://www.cdc.gov/obesity/data/adult.html

Clayton, D. & James, L. (2015). The effect of breakfast on appetite, gulation, energy balance and exercise performance. *Proceedings of the Nutrition Society*, 75(03), pp.319-327.

Deshmukh-Taskar, P., Nicklas, T., Radcliffe, J., O'Neil, C., & Liu, Y. (2012). The relationship of breakfast skipping and type of breakfast consumed with overweight/obesity, abdominal obesity, other cardiometabolic risk factors and the metabolic syndrome in young adults. The National Health and Nutrition Examination Survey (NHANES): 1999–2006. *Public Health Nutrition*, *16*(11), 2073-2082. http://dx.doi.org/10.1017/s1368980012004296

English, K., & Paddon-Jones, D. (2010). Protecting muscle mass and function in older adults during bed rest. *Current Opinion In Clinical Nutrition And Metabolic Care*, *13*(1), 34-39. http://dx.doi.org/10.1097/mco.0b013e328333aa66

Halton T, Hu F. (2004). The effects of high protein diets on thermogenesis, satiety and weight Loss: A critical review. *Journal of the American College of Nutrition,* 23, 373-385.

Jakubowicz D and Froy O. (2013). Biochemical and metabolic mechanisms by which dietary whey protein may combat obesity and type 2 diabetes. *J Nutr Biochem* 24(1):1-5

Kim, J., Wilson, J., & Lee, S. (2010). Dietary implications on mechanisms of sarcopenia: roles of protein, amino acids and antioxidants. *Sciencedirect.com*. Retrieved 8 March 2017, from http://www.sciencedirect.com/science/article/pii/S0955286309001387

Layman, D., Anthony, T., Rasmussen, B., Adams, S., Lynch, C., Brinkworth, G., & Davis, T. (2015). Defining meal requirements for protein to optimize metabolic roles of amino acids. *The American Journal Of Clinical Nutrition*, *101*(6), 1330S-1338S. http://dx.doi.org/10.3945/ajcn.114.084053

Leidy, H., Ortinau, L., Douglas, S., & Hoertel, H. (2013). Beneficial effects of a higher-protein breakfast on the appetitive, hormonal, and neural signals controlling energy intake regulation in overweight/obese, "breakfast-skipping," late-adolescent girls. *The American Journal Of Clinical Nutrition*, *97*(4), 677-688. http://dx.doi.org/10.3945/ajcn.112.053116

Mamerow, M., Mettler, J., English, K., Casperson, S., Arentson-Lantz, E., & Sheffield-Moore, M. et al. (2014). Dietary protein distribution positively influences 24-h muscle protein synthesis in healthy adults. *The Journal Of Nutrition*, *144*(6), 876-880. http://dx.doi.org/10.3945/jn.113.185280

Manini T. (2010). Energy expenditure and aging. *Ageing Res Rev*. 9(1):1-11. doi:10.1016/j.arr.2009.08.002.

Pesta, D., & Samuel, V. (2014). A high-protein diet for reducing body fat: mechanisms and possible caveats. *Nutrition & Metabolism*, *11*(1), 53. http://dx.doi.org/10.1186/1743-7075-11-53

Timlin, M., & Pereira, M. (2008). Breakfast frequency and quality in the etiology of adult obesity and chronic diseases. *Nutrition Reviews*, *65*(6), 268-281. http://dx.doi.org/10.1111/j.1753-4887.2007.tb00304.x

U.S. Department of Agriculture; U.S. Department of Health and Human Services. (2010). *Dietary Guidelines for Americans*, 7th ed.; U.S. Government Printing Office: Washington, DC, USA

Veldhorst M, Smeets A, Soenen S. (2008).Protein-induced satiety: Effects and mechanisms of different proteins. *Physiol Behav*. 94(2):300-307. doi:10.1016/j.physbeh.2008.01.003.

Wolfe, R., Miller, S., & Miller, K. (2008). Optimal protein intake in the elderly. *Clinical Nutrition*, *27*(5), 675-684. http://dx.doi.org/10.1016/j.clnu.2008.06.008