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Christina Crowder
University of Arkansas, Fayetteville

Brianna I. Neumann
University of Arkansas, Fayetteville

Jamie I. Baum
University of Arkansas, Fayetteville

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The effect of breakfast protein source on postprandial hunger and glucose response in normal weight and overweight young women

Christina Crowder^{*}, Brianna L. Neumann[†], and Jamie I. Baum[§]

ABSTRACT

Breakfast consumption has been linked to health benefits such as improved weight regulation and glucose control. Studies have shown higher protein breakfasts lead to a greater reduction in hunger compared to breakfasts higher in carbohydrates. However, few studies have examined the impact of higher protein breakfasts from differing protein sources. The objective of this study was to determine if protein quality (animal (AP) versus plant (PP) protein) influences postprandial appetite, food cravings, food intake and glucose response in participants consuming a high protein breakfast (~30% energy from protein). We hypothesized that AP would be more satiating than PP. Normal weight (NW; n = 12) and overweight women (OW; n = 8) ages 18-36 were recruited to participate. All participants completed two visits in a randomized, cross-over design with one week between visits. Blood glucose and appetite were assessed at 0, 15, 30, 45, 60, and 120 min postprandial. Participants kept a 24-h dietary record for the duration of each test day. Participants preferred the appearance of the AP meal compared to the PP ($P < 0.05$). No difference was found between NW and OW participants or breakfasts for postprandial appetite responses. The AP had a significantly lower ($P < 0.05$) glucose response at 30 min compared with PP (-11.6%; 127 + 4 versus 112 + 4 mg/dL) and a slower return to baseline. There was no significant difference in daily energy intake between breakfasts. These data suggest protein source influences postprandial glucose response without significantly impacting appetite response and food intake in regular breakfast consumers.

* Christina Crowder is a May 2015 Honors Program graduate with a major in Food, Human Nutrition, and Hospitality and a Dietetics Concentration.

† Brianna L. Neumann is a Masters student in the Department of Food Science.

§ Jamie I. Baum is a faculty mentor and assistant professor in the Department of Food Science.

MEET THE STUDENT-AUTHOR



Christina Crowder

I am from Tulsa, Oklahoma I graduated from the University of Arkansas in May 2015 with a major in Human Nutrition and Hospitality Innovation with a concentration in Dietetics. This project was my Honors Thesis under Dr. Jamie Baum, in which I studied the role of dietary protein on body composition, energy metabolism and metabolic health in young women. In support of my major, I accepted internships in the summer of 2013 with Chartwells Marketing at the University of Arkansas-Fayetteville, and with St. Vincent Sports Performance in Indianapolis, Ind., for the sports dietitian. I served as Director of Dining Services for the Associated Student Government from 2012-2013 and as Campus Life Director during the fall semester of 2013. I served on the Bumpers Honors Student Board as the Outstanding Project/Thesis Competition Director for 2013-2014 and in 2015 as Vice Chair. I will be completing a dietetic internship to receive my Registered Dietitian Nutritionist (RDN) credential at Duke University Hospital in Durham, N.C. next year. Then, I likely will attend graduate school for nutrition to pursue a career in teaching, research, and clinical practice. This project was made possible by Dr. Jamie Baum, Brianna Neumann, the Bumpers College, and the Honors College of the University of Arkansas.

INTRODUCTION

Early adulthood is a vulnerable life stage for weight gain, especially among women. The average weight gain for women between the ages of twenty and thirty is 12-25 lbs (Hutchesson et al., 2013). Weight gain during early adulthood increases the risk of a number of chronic health conditions such as type 2 diabetes mellitus, depression, polycystic ovary syndrome, and infertility. After the age of eighteen years, women are 1.9 times more likely to develop type 2 diabetes if body weight increased 10-16 pounds and 2.7 times more likely to develop type 2 diabetes if body weight increased 16-22 pounds (Hutchesson et al., 2013).

Breakfast has been defined as the first meal of the day, eaten before or at the start of daily activities (e.g., errands, travel, work, etc.), within two hours of waking, typically no later than 10:00 AM, and containing an energy level between 20% and 35% of daily energy needs (Timlin and Pereira, 2007). There are many benefits associated with eating a healthy breakfast such as improved micronutrient intake, decreased incidence of overweight and obesity, and lower cholesterol levels (Ruxton and Kirk, 1997; Pollitt and Matthews, 1998; Stanton and Keast, 1989; Keski-Rahkonen et al., 2003). Several studies have shown that individuals who eat breakfast tend to weigh less than those who regularly skip breakfast (Deshmukh-Taskar et al., 2010; 2013).

Consuming more protein (20–30 g) at breakfast may increase subjective feeling of fullness and satiety, compared to a standard cereal-based breakfast containing 10–15 g of protein (Blom et al., 2006; Veldhorst et al., 2009b). A recent study found that when adults ate eggs for breakfast, they stayed fuller throughout the day (Vander Wal et al., 2008). Another study comparing a protein-based breakfast to a carbohydrate-based breakfast found that overweight women who ate the protein-based breakfast five times a week for eight weeks lost 65% more weight and reduced their waist circumference by 83% more than those participants eating a carbohydrate-based breakfast (VanderWal et al., 2008).

Protein quality may also influence postprandial (also known as post-meal) satiety response. Protein quality is defined as the ability of protein to achieve certain metabolic actions within the digestion, absorption, and assimilation process. Two important aspects of protein quality include a) the individual protein and food matrix within which it is consumed, and b) the availability of essential and conditionally essential amino acids (Millward et al., 2008). Plant-derived protein, with the exception of soy, is considered incomplete because it lacks one or more amino acids necessary for growth and development. Animal proteins are complete proteins that contain all the necessary amino acids. Protein quality is important because although equal quantities of plant and animal protein may have the same caloric content, the digestibility and content of amino acids have notable effects on blood glucose regulation (Millward et al., 2008).

One study comparing the satiating effects of whey protein as compared to casein and soy protein demonstrated that within both low and high protein diets (10% or 25% energy), whey has greater satiating effects due to decreases in subjective hunger (Veldhorst et al., 2009a). Another study compared satiety response of mixed macronutrient meals with differing protein sources (egg albumin, pea protein, soy protein, casein, gelatin, or wheat gluten) and found no differences in satiety response between protein sources (Lang et al., 1998). This finding could be attributed the addition of fat and carbohydrate from the mixed meal, which may delay gastric emptying, negating any post-absorption differences in the proteins. The studies mentioned above measured satiety following consumption of a liquid meal. However, most breakfast meals are consumed as whole foods. Therefore, the objective of this study was to determine if protein quality (plant protein versus animal protein) at breakfast influenced satiety, glucose response and decreased daily food intake.

MATERIALS AND METHODS

Subjects. Recruitment was performed between October 2014 and February 2015 through the Department of Food Science at the University of Arkansas. The study protocol was approved by the Office of Research Compliance Institutional Review Board of the University of Arkansas. Subjects were recruited into the study using the University of Arkansas Newswire (the university's daily newsletter). The selection was carried out with a phone interview, and exclusion criteria included the following: underweight (BMI \leq 18.4), current smoker, current medication usage (except hormonal birth control), food allergies or dislike of the foods served during the study, and/or diagnosis of metabolic disease (e.g. diabetes). Subjects signed a consent form before participating in the study. The participants were recruited on a rolling basis and assigned to a treatment group based on BMI (Normal Weight or Overweight).

Study Design. Twenty-two healthy, female adults 18-36 years of age were enrolled in the study. Subject characteristics can be found in Table 1. Once enrolled in the study, subjects were assigned to either the normal weight (NW; $n = 14$) or overweight (OW; $n = 8$) group based on BMI. The study was conducted using a randomized, cross-over design in which each participant received two different breakfasts, animal protein-based (AP) and plant protein-based (PP), with at least a one-week washout period between each test day breakfast. Subjects were instructed to fast for at least 8 hours overnight prior to the study days and limit their

Table 1. Subject characteristics.

Characteristics	NW [‡]	OW
Participants (n)	8	12
Age (y) [†]	25 \pm 1	25 \pm 1
Weight (kg)	61.3 \pm 2.1 [§]	87.8 \pm 7.8 ^b
Height (m)	1.66 \pm 1.2	1.65 \pm 1.8
BMI (kg/m ²)	22.2 \pm 0.6 ^a	31.9 \pm 2.7 ^b
Ethnicity		
Asian	2	0
Caucasian	7	6
Indian	2	1
Latina	1	1

[†] Age, weight, height and BMI are expressed as means \pm SEM.

[‡] NW = normal weight participants;

OW = overweight participants.

[§] Means in a row without a common letter are significantly different ($P < 0.05$).

physical activity the day prior to data collection. On each data collection day, food items for breakfast were portioned, weighed, and labeled appropriately for each subject. Subjects were given 15 minutes to consume the test breakfast. The participants were asked to evaluate the taste and appearance of the breakfast on a visual analog scale (VAS). Blood glucose and appetite were analyzed at 0, 15, 30, 45, 60, 90, and 120 min after each test breakfast. In addition, subjects were asked and instructed to keep food records for the rest of each test day.

Breakfast Composition. The nutrient composition of the test breakfasts can be found in Table 2. The PP and AP breakfasts were similar in calories, carbohydrates, fat, and

Table 2. Nutrient composition of test breakfasts.

Dietary Characteristics	Animal-Protein Breakfast (AP)	Plant-Protein Breakfast (PP)
Total Kcal	357 [†]	371
Protein (g)	27	26
Fat (g)	12	11
Carbohydrate (g)	38	46
Fiber (g)	4	5
Breakfast Appearance, mm ¹	74.8 \pm 3.6 [‡]	63.6 \pm 3.5 ^b
Breakfast Palatability, mm ¹	73.1 \pm 3.5 ^a	65.9 \pm 3.8 ^a

[†] Values are expressed as means \pm SEM, $n = 20$.

[‡] Means in a row without a common letter are significantly different ($P < 0.05$).

fiber. This allows for a controlled comparison of protein source.

Body Height and Weight, and Body Mass Index (BMI). Body height was measured to the nearest 0.01 cm using a stadiometer (Detecto, St. Louis, Mo.) with subjects barefoot, in the freestanding position. Body weight was measured in the fasting state with subjects without shoes to the nearest 0.01 kg using calibrated balance scales (Detecto, St. Louis, Mo.). Body mass index (BMI) was calculated as weight (kg) divided by height (m) squared.

Dietary Assessment. The energy and macronutrient composition of test breakfast meals and the 1-day dietary records were analyzed using the Genesis R&D diet analysis software package (Salem, Ore.).

Blood Glucose. After an overnight fast, blood glucose samples were measured in duplicate via finger stick at 0, 15, 30, 45, 60, 90, and 120 min postprandial using a LifeScan One Touch UltraSmart System (New Brunswick, N.J.).

Appetite and Palatability Assessment. Participants were asked to rate their perceived hunger, fullness, perceived desire to eat, prospective food consumption, desire for something sweet, and desire for something savory using a 100-mm visual analog scale (VAS; Flint et al., 2000). In addition, subjects were asked to rate how much they liked the taste and appearance of the test breakfasts using a Visual Analog Scale (VAS). The VAS is a validated questionnaire incorporating a 100-mm horizontal line scale with questions worded as “how strong is your feeling of” and end anchors of “not at all” to “extremely.”

Statistical Analysis. In order to analyze the effect of the dietary treatments (e.g. breakfast types), Repeated Measures Analysis of Variance Two-Way (ANOVA) was used and Tukey’s posthoc test was used for multiple comparisons between groups. In order to analyze the effect of each breakfast over time, AUC (area under the curve) was calculated using the trapezoidal rule (Allison et al., 1995). Area under the curve was then analyzed using One-Way ANOVA using Bonferonni posthoc analysis for multiple comparisons between groups. In cases where no differences between body weight groups existed, the groups were combined to analyze AP versus PP by Paired *t*-test. These analyses were used to determine differences in blood glucose response, hunger, satiation, palatability, and 24-h energy intake between the plant protein break-fast and animal protein breakfast. GraphPad Prism Software v 6.0 (La Jolla, Calif.) was used for all data analysis.

RESULTS AND DISCUSSION

This is one of the first studies to examine the effect of complete meals, similar in caloric content, consisting of

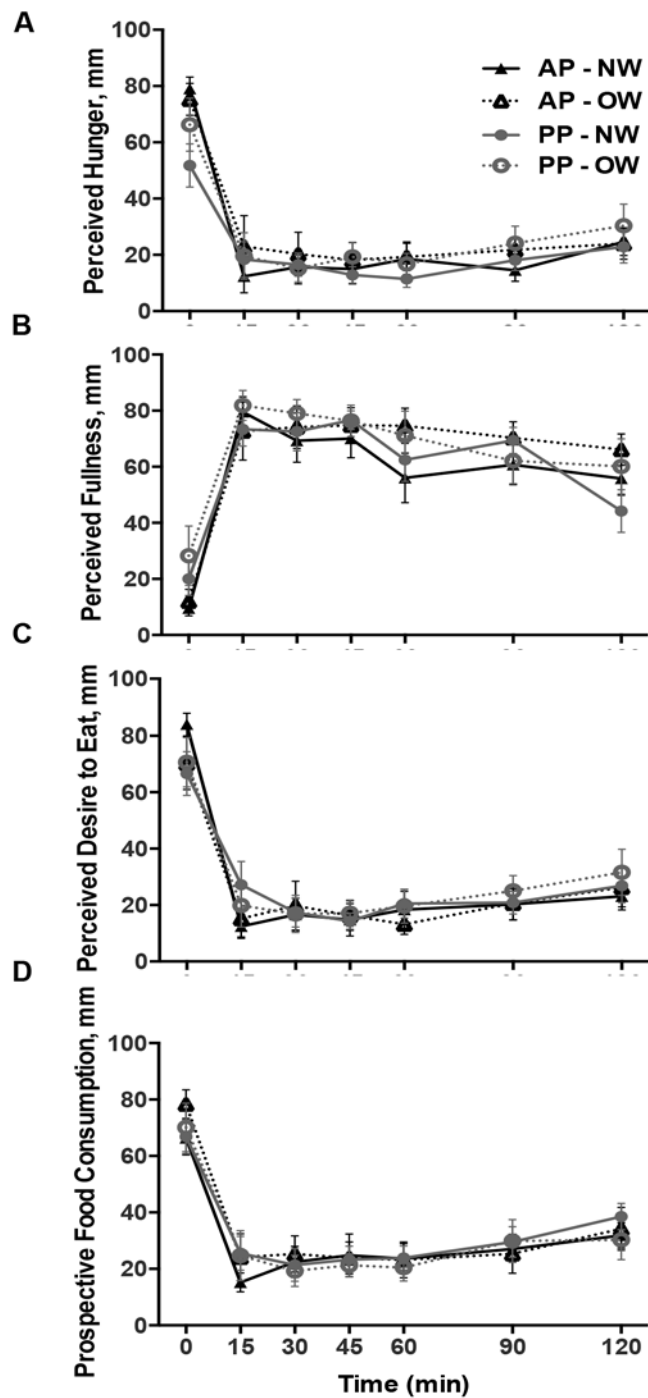


Fig. 1. Appetite responses following test breakfasts. Values expressed as means \pm SEM. Data are depicted as appetite rating over time per weight group and breakfast type and net incremental area under the curve (niAUC). (A) Perceived hunger. (B) Perceived fullness. (C) Perceived desire to eat. (D) Prospective food consumption. AP = animal protein; NW = normal weight; OW = overweight; PP = plant protein.

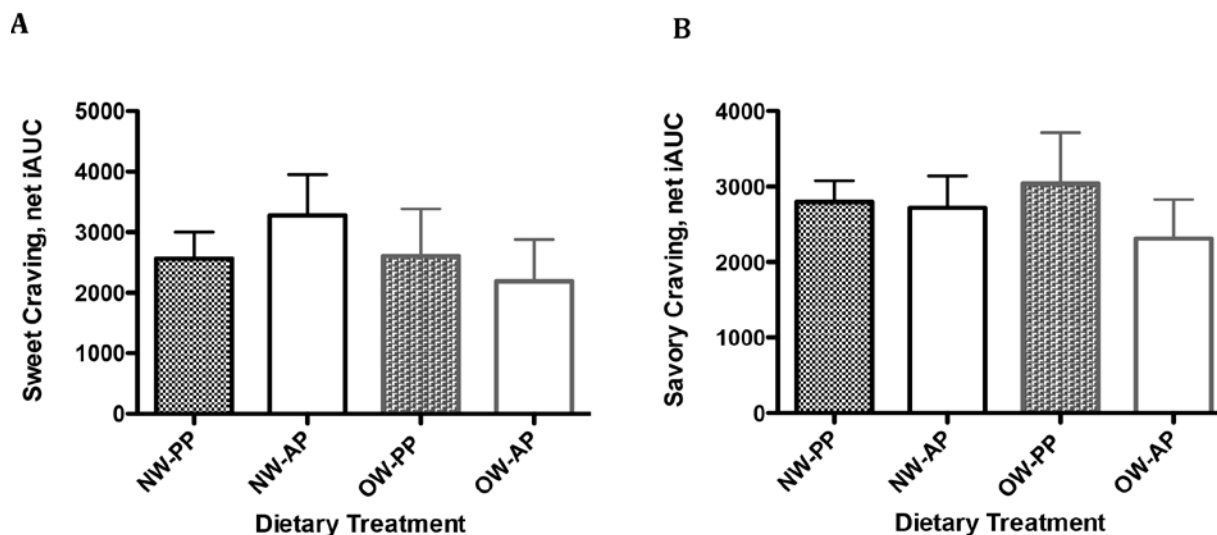


Fig. 2. Food craving response following the test breakfast. Values expressed as means \pm SEM. Data are depicted as food craving rating net incremental area under the curve (niAUC). (A) Sweet craving following the test breakfast. (B) Savory craving following the test breakfast.

plant protein versus animal protein, on appetite and postprandial glucose response in normal weight and overweight individuals. The present study led to the conclusion that there is no difference in the effect of protein source (animal versus plant) on appetite (Fig. 1), food cravings (Fig. 2), or daily food intake (Table 3). Protein source may have an influence on postprandial glucose response at 30 min postprandial; however further studies are needed to confirm these findings (Fig. 3). Although no difference in postprandial satiety response between animal or plant protein was detected, these results were not unexpected. Several studies have compared the effect of protein source on satiety within a mixed meal (Veldhorst et al., 2009a; Lang et al., 1998; Lang et al., 1999; Marsset-Baglieri et al., 2015; Douglas et al., 2015), demonstrating equal satiety responses to plant and animal proteins within higher protein meals (>22% protein). In addition, a majority of studies have demonstrated no difference in satiety response to pure proteins, aside from some minor variations that were related to rate of absorption (Veldhorst et al., 2009b; Luhovyy et al., 2007). At lower meal concentrations (10% protein), whey protein (an animal source of protein) seems to exert a greater satiating effect, perhaps

due to branched-chain amino acid concentration, but this concentration is much lower than the concentration of animal protein tested in the current study (Veldhorst et al., 2009a). This study used test meals similar in caloric content with matched macronutrient compositions; therefore, we did not expect to find large variations in postprandial satiety response between test meals (Fig. 1).

This study appears to be the first to examine how protein source influences food cravings (Fig. 2). Although we did not find any significant differences in food cravings, the OW subjects tended to have lower cravings for sweet and savory foods following the AP breakfast; however, the same response was not observed in the NW group. However, more research is needed to confirm these findings. Hoertel et al. (2014) found that subjects consuming a high protein diet had lower sweet and savory cravings than subjects who consumed normal protein or skipped breakfast. This study supports the data from our study in terms of craving. However, in our study we did not observe differences in ad libitum food intake between diets (Table 3). The specific “sweet or savory” qualities of the foods consumed post-breakfast were not recorded, but these data could be further investigated with subsequent studies.

Table 3. Twenty-four hour nutrient intake.

Nutrient	AP-NW [†]	AP-OW	PP-NW	PP-OW
Energy (kcal)	2327 \pm 141	2417 \pm 251 [‡]	2041 \pm 161	2218 \pm 269
Carbohydrate (g)	271 \pm 13.3	275.6 \pm 22.9	308.18 \pm 55.6	237.6 \pm 35.3
Fat (g)	93.5 \pm 11.4	100.4 \pm 13.7	83.1 \pm 19.8	95.6 \pm 13.7
Protein (g)	123.1 \pm 20.9	107.3 \pm 20	107.4 \pm 10.5	93.4 \pm 14.1

[†] AP = animal protein; NW = normal weight; OW = overweight; PP = plant protein.

[‡] Values are expressed as means \pm SEM.

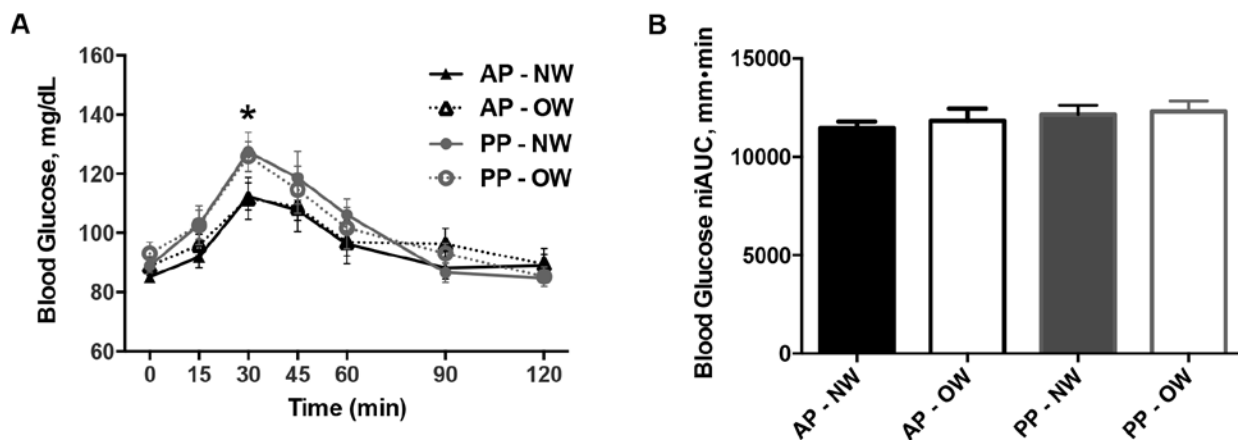


Fig. 3. Glucose response to the test breakfasts. (A) Glucose response to the test breakfasts over time. (B) Glucose net incremental area under the curve (niAUC). Values expressed as means + SEM. * indicates that blood glucose values for AP were significantly different than PP ($P < 0.05$). AP = animal protein; NW = normal weight; OW = overweight; PP = plant protein.

An increase in protein intake throughout the day, starting with breakfast, may help an individual to feel more satisfied and respond to neural signals of satiety and blood glucose regulation (Woods, 2009). Additionally, the OW subjects tended to consume less protein and more calories compared to the NW over the remaining 24-h period; however these values were not significant, possibly due to the small number of subjects. The underlying mechanism is still unknown, but high protein diets seem to spontaneously reduce food intake in individuals and could be attributed to protein's satiating effect (Anderson and Moore, 2004).

Despite no statistically significant differences between glucose response over the 2-h period between meals or subjects (Fig. 3), there was a trend for more stable postprandial glucose response following the AP breakfast for both NW and OW groups. In addition, subjects consuming the PP breakfast has significantly higher ($P < 0.05$) blood glucose levels 30 min postprandial. The control of postprandial glucose levels is important for diabetes risk (Leiter et al., 2005; Boden et al., 2005) and minimizing cardiovascular disease risk and pathogenesis. In general, both isocaloric and hypocaloric diets with increased protein in general lead to more stable postprandial glucose levels with lesser peak excursions and incremental area under the curve (O'Keefe et al., 2008; Farnsworth et al., 2003; Layman et al., 2003; Gannon and Nuttall, 2006). There is uncertainty as to why there were greater postprandial glucose levels for both NW and OW following the PP breakfast, but this could be attributed to the slight disparity in breakfast carbohydrate content or differing amino acid profiles. It has been observed that healthy individuals and those with postprandial glucose levels on the higher end of normal may do better with a high animal protein based breakfast, with high protein in general

preferred over low protein/carbohydrate based breakfast (Leidy et al., 2014).

One of the limitations of this study is the short postprandial data collection period following breakfast consumption. Two hours postprandial may not be enough time to fully capture the postprandial satiety response, as meals are generally four to five hours apart and initiated by habit or hunger (Woods, 1991). Many studies take measurements for four hours following treatment to ensure subjects return to baseline (Leidy and Racki, 2010; Leidy et al., 2014; Douglas et al., 2015). The small discrepancy in caloric values of the meals may have been why we see small changes in postprandial blood glucose. We do not think these differences are significant enough to affect any of the glucose values, but we cannot ignore the possibility that the small difference produced some effect. In addition, food records have been proven inaccurate in terms of self-report energy intake. Dhurandhar et al. (2014) present a strong case for the discontinuance of subjective energy intake reporting methods, but until more advanced reporting methods are developed and accessible, the 24-h dietary food records will have to suffice. Additionally, assays for ghrelin, GLP-1, and serum insulin could be used for objective satiety measurements along with subject visual analog scales (VAS).

Overall, there was no difference in the response between normal and overweight subjects following either the AP or PP breakfasts. However, subjects had a higher glucose response at 30 min following the PP breakfast. There was no difference in postprandial satiety response between breakfasts. Overweight subjects tended to consume more calories following both breakfasts and more calories from fat compared to normal weight subjects and normal weight subjects consumed more calories from protein. With these

findings, recommendations are for both normal weight and overweight individuals to consume high quality, higher protein breakfasts.

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