

HUMAN NUTRITION

Title: The effect of increasing the protein content of breakfasts on satiety and cognitive function in undergraduate students – NPB # 12-147 revised

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Industry summary

This study investigated the effect of protein consumption at breakfast on appetite and cognitive performance. Participants were provided with one of four breakfast treatments: no breakfast, No-pork, high-CHO/low pork protein and low-CHO/high pork protein. Baseline appetite questionnaires and plasma samples were collected and cognitive performance tests were administered at regular intervals for 240 minutes following breakfast. A lunch meal was provided 240 minutes after breakfast, and the amount eaten recorded. Following the lunch meal, participants were allowed to leave the laboratory and food intake was recorded using a food log and hourly appetite questionnaires completed for the rest of the day. Eating breakfast reduced subjective appetite compared to eating no breakfast. While food intake at the lunch meal was lowest after the HP breakfast total daily energy intake was lowest when participants consumed no breakfast. The amount of protein eaten at breakfast has no effect on food intake during the test day. However, plasma glucose levels were lower following the low CHO/high protein breakfast compared to the other breakfast meals. For the cognitive tests, proactive interference in delay memory was sensitive to treatment) with the low CHO/high protein treatment reducing interference. Verbal fluency was sensitive to overall treatment, and reflected a stronger effect of the low CHO/high protein breakfast over time. Verbal fluency was marginally sensitive to the treatment ($p = .068$), with the two protein treatments leading to continued improvement over time. In conclusion, consuming pork protein at breakfast had no effect on appetite and food intake but provided marginal benefits for cognitive performance.

Keywords:

Protein, Appetite, Cognitive performance, Breakfast, Insulin, Plasma glucose

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Scientific abstract

The effect of protein consumption at breakfast on appetite and cognitive performance was investigated using a randomized, cross-over study design. Following an overnight fast, 33 healthy, college undergraduates (aged = 22 ± 2 yrs, BMI = 23.5 ± 1.7 kg/m²) were provided one of four breakfast treatments: no breakfast, CHO-only, high-CHO/low protein and low-CHO/high protein. Baseline appetite questionnaires and plasma samples were collected and cognitive performance tests were administered at regular intervals for 240 minutes following breakfast. An ad libitum lunch meal was provided 240 minutes after breakfast, and the amount eaten recorded. Following the lunch meal, participants were allowed to leave the laboratory and food intake was recorded using a food log and hourly appetite questionnaires completed for the rest of the day. Eating breakfast reduced subjective appetite compared to eating no breakfast ($p < 0.05$). While food intake at the lunch meal was lowest after the HP breakfast ($p < 0.05$) total daily energy intake was lowest when participants consumed no breakfast ($p < 0.05$). The macronutrient composition of the breakfast meal had no effect on subjective appetite or food intake ($p > 0.05$). Analysis of plasma samples revealed a significantly lower glucose following the low CHO/high protein treatment as compared to the CHO only breakfast. ($p < 0.05$). Plasma insulin concentration was lowest following the no breakfast condition ($p < 0.05$) but did not differ following the different breakfast meals ($p > 0.05$). Proactive interference in delay memory was sensitive to treatment ($p = .056$), the low CHO/high protein treatment reducing interference. Verbal fluency was sensitive to overall treatment ($p < .05$), and reflected a stronger effect of the low CHO/high protein breakfast over time. Verbal fluency was marginally sensitive to the treatment ($p = .068$), with the two protein treatments leading to continued improvement over time.

Introduction

Throughout the developed world, the number of overweight and obese adults has risen markedly over the past few decades. This is of some concern as these conditions are associated with increased risk of developing chronic diseases such as type 2 diabetes (Colditz et al. 1990; Cassano et al. 1992; Lipton et al. 1993), cardiovascular disease (Lavie et al. 2009) or cancer (Larsson and Wolk 2007; Yang et al. 2009; Urayama et al. 2011). Consequently, reducing the number of overweight or obese individuals is a leading public health goal in developed countries. Accumulating evidence suggests that the transition from living at home to university can

be a time of significant and rapid weight gain for undergraduate students (Levitsky et al. 2004; Hoffman et al. 2006; Gropper et al. 2011) with weight gain among university students being nearly six times the population average (Mihalopoulos et al. 2008). Consequently, university students would appear to be a group where interventions to prevent weight gain are warranted. These efforts would be aided by research that identifies dietary strategies that augment satiety and potentially aid weight management.

A key aspect of a healthy diet is the regular consumption of breakfast (Kant et al. 2008; Deshmukh-Taskar et al. 2010). In addition to the positive effect on nutrient intake, data indicates that regular breakfast consumers have a lower body weight (Summerbell et al. 1996; Cho et al. 2003) and a reduced risk of weight gain over a 10 year period (van der Heijden et al. 2007) than breakfast skippers. While the regular consumption of breakfast appears to aid weight management the benefits of this dietary habit may be further enhanced by the selection of a breakfast meal that provides a mix of macronutrients that augment satiety. For instance, many breakfast foods, such as ready-to-eat cereal, white bread or bagels, are high GI foods and as a consequence may be poorly satiating (Ball et al. 2003; Krog-Mikkelsen et al. 2011). While low GI breakfast foods are available they may not be acceptable to all consumers due to lower palatability (Warren et al. 2003). An alternative strategy is to replace some of the carbohydrates in a high GI breakfast with protein which is generally accepted to be the most satiating macronutrient (Halton and Hu 2004; Weigle et al. 2005; Paddon-Jones et al. 2008).

To date, only a limited number of studies have investigated the effect of increasing protein intake at breakfast on satiety. These studies have shown that increasing the protein content of breakfast increases satiety in adolescents (Leidy and Racki 2010) and adults (Stubbs et al. 1996; Vander et al. 2005; Hursel et al. 2010; Ratliff et al. 2010). Moreover, protein consumed at breakfast is more satiating than protein consumed at lunch or the evening meal (Leidy et al. 2009). Based on this data, it would appear that replacing high GI carbohydrates with a protein, such as pork, would augment satiety and may aid weight management.

In addition to an effect on appetite, the potential for foods to influence behavior is increasingly being recognized and it is possible that foods may be utilized to improve cognitive function over and above normal levels. While it has been well established that skipping breakfast has deleterious effects on cognition (Pollitt et al. 1981; Connors and Blouin 1982; Wesnes et al. 2003; Mahoney et al. 2005) less is known about how the macronutrient composition of breakfast influences cognitive function. Several studies have shown that the administration of glucose influences cognitive function (Kennedy and Scholey 2000; Scholey and Kennedy 2004; Owen et al. 2012). However, pure glucose is rarely consumed as part of a normal diet although plasma glucose may influence cognitive function. While a high GI food may improve short-term cognitive function due to the availability of glucose the effect may be short-lived due to the rapid fluctuation in plasma glucose concentration (Jenkins et al. 1981). Indeed, a limited number of studies have found that a low GI breakfast has beneficial effects on cognitive function in schoolchildren compared to a high GI breakfast (Benton et al. 2007; Micha et al. 2010). The addition of protein to a high GI breakfast may improve cognitive function by reducing the glycemic response of the meal (Moghaddam et al. 2006) and it has been found that a protein rich or macronutrient balanced breakfast results in better overall cognitive performance (Fischer et al. 2002).

Objectives

This proposed project will determine the effect of increasing the protein content of breakfasts that differ in GI on satiety and cognitive performance. Specific hypotheses are that increasing the protein content of breakfast from will:

- 1) Reduce subjective appetite
- 2) Reduce post-prandial plasma insulin concentration
- 3) Reduce post-prandial plasma glucose concentration
- 4) Improve cognitive performance during the morning period

Materials & Methods

Thirty three relatively healthy adults will be recruited for this proposed study. The study group will consist of males and females from any racial or ethnic group. Participants will be recruited subject to the following criteria:

Inclusion criteria

Aged between 18-25 years

Body mass index 20-25 kgm⁻²

Regularly consumes (>5 days each week) breakfast

Registered undergraduate

Rates the palatability of the study foods > 6 on a 9 point scale

Exclusion criteria

Has a alcohol intake over 40g day

Report a weight change > 3kg in previous 3 months

Presence of diagnosed chronic disease (e.g., cancer, heart disease, type 1 or 2 diabetes)

Uses tobacco products

Recent or planned changes in medication use

Presence of acute illness

A restrained eater (>13 on the restraint section of the three-factor eating questionnaire) (Stunkard & Messick, 1985)

Body weight changes by > 2.5kg during the study period

It will be determined if participants meet the inclusion/exclusion criteria using a questionnaire. Details regarding the participant's usual breakfast habits (eating time, breakfast foods eaten etc.) will be collected.

Study protocol

This study used a randomized cross-over design. All participants were required to report to the laboratory on four separate occasions separated by at least one week. Participants were asked to refrain from drinking alcohol or strenuous exercise in the 24 hours before each test session. They were also asked to refrain from drinking caffeinated beverages for 12 hours prior to each test session. The participant was provided with all their meals on the day before each test session which were standardized across test sessions.. For each test session, participants were required to report to the Nutrition and Wellness Research Center at Iowa State University at 7:30am following an overnight fast (10 – 12 hours). An indwelling catheter was placed into the participant's non-dominant arm by the study nurse and the participant allowed to rest for 30 minutes to acclimatize to the catheter. Then, a baseline blood draw was made and the participant asked to complete a standard appetite questionnaire. The participant was then be provided with one of four meals in a random order: no breakfast meal, high protein/low CHO, low protein/high CHO, CHO/no animal protein. They were required to eat this meal in its entirety within 15 minutes. On completion of the meal another blood draw was made and an appetite questionnaire completed (t0). Further blood draws and appetite questionnaires were completed at t0+15, 30, 60, 120, 180 and 240 minutes. In addition, at t0+, 30, 60, 120, 180 and 240 minutes a battery of cognitive performance and well-being tests were administered. While in the laboratory, the participant were allowed to use their computer, read or watch television but were not be allowed to leave the study area. After the final blood draw the indwelling catheter will be removed from the participants arm and they will be allowed to rest for five minutes before being presented a lunch meal.

Test meals

The three test meals used in this study were based on commonly eaten breakfast foods (English muffin, low fat pork breakfast sausage, low fat spread and orange juice). The participants received a breakfast that provided 20% of their estimated daily total energy expenditure which was estimated using validated equations to estimate basal metabolic rate (Schofield 1985) and multiplying that figure by 1.5.

	CHO (%)	Protein (%)	Fat (%)	Fiber (g)
HP/LC	40	30	30	0.45
LP/HC	58	12	29	0.45
CHO only	61	10	29	0.45

Table one – macronutrient distribution of the test meals

The amount of each component of the meal used in the test meals is provided in table 2.

	Muffin (g)	Low-fat spread (g)	pork (g)	Orange juice (g)	Water (g)	Energy (Kcal)	Weight (g)
HP/LC	45	15	135	225	0	459	420
LP/HC	90	20	20	225	65	461	420
CHO group	110	20	0	225	65	460	420

Table 2 – the ingredient list of the test meals

Following the final blood draw a test meal of pasta mixed with

tomato sauce and cheese was provided as a further measure of satiety. The ingredients in this meal were mixed to provide a 'homogenous' type meal. The participant was presented with the meal and instructed to eat until comfortably full.

Subjective appetite measurement

Subjective appetite was determined using a questionnaire that poses standard appetite questions. These were: How hungry do you feel right now? How full do you feel right now? What is your desire to eat right now? What is your prospective consumption right now? What is your desire to eat something sweet right now? What is your desire to eat something salty right now? What is your desire to eat something fatty right now? What is your desire to eat something savory right now? Answers were captured on a visual analogue scale contained on a PalmPilot handheld computer. Answers were captured and stored with a time and date stamp so compliance to the study protocol could be determined. Participants were required to maintain this appetite log at set times while in the laboratory and every hour for the remainder of their waking hours outside the laboratory. A timer with an alarm was provided to aid compliance to the protocol.

Measurement of food intake

After leaving the laboratory the participant were required to maintain a food diary for the rest of the day to determine their food intake. Participants were trained in the use of a food log before leaving the laboratory during the first test session. Data from the food logs were analyzed using Nutritionist Pro. The PI (Dr Hollis) has experience in the use of diet diaries and their analysis (Hollis and Mattes 2007; Hollis and Mattes 2007; Hollis et al. 2009).

Metabolic and endocrine markers of satiety

Blood was drawn into EDTA coated vacutainers mixed with the relevant preservative and centrifuged. The plasma were collected and stored at -80C until being assayed. Plasma was assayed for insulin using radioimmunoassay and glucose using a metabolic analyzer.

Cognitive and wellbeing assessment

The psychological battery was designed to measure five constructs that are known to vary systematically over time within and to be sensitive to within person intrinsic variables (e.g., stress, circadian variation, mood). Additionally, previous research demonstrates each of the measures can be reliably measured over time within

participants. This is an essential element of each of the measures given that each test will be administered 20 times to each participant.

Short PANAS: Variation in mood related to the experimental manipulation were measured by having each individual rate their current mood on 8 adjectives (bored, sad, energetic, amused, calm, angry, happy, anxious) at 6 points across the session. Ratings were collected by having the participant place a mark on a 10 cm line bound by the statements “not at all” or “extremely” with a pencil. The use of the bounded line rather than discrete values (e.g., 1-10) is designed to reduce subjects’ reliance on memory of previous responses in making their rating and instead to respond based upon their current mood. Outcomes included rating for the individual adjectives and composite measures of positive and negative affect.

Immediate and Delayed Memory: A verbal learning task was used to assess immediate and delayed memory. In this task individuals were asked to learn and recall a 15 item list of words. The task included two learning trials and a delayed recall trial for each of the points of measurement. For the learning trials (immediate memory), subjects first heard the words presented one at a time and then recalled as many of the words as possible. For the retention trial (delayed memory), subjects were asked to recall as many of the words as they can after completing the fluency, Stroop and speed of processing tasks. A unique word lists from the Repeatable Episodic Memory Task (Parker et al., 1995) will be used for each point of measurement. Outcomes included 1) short-term retention representing recall for learning trial 1, 2) consistency of recall across the learning trials, and 3-4) retention and forgetting from delayed recall. These measures are sensitive to within person variability related to circadian variation over days of testing (Murphy et al., 2007).

Letter Fluency: This is a commonly used measure of executive function and to a lesser degree semantic memory. In this task individuals were asked to generate as many words as possible beginning with a certain letter in 1 minute. The two constrains are that individuals were told they cannot repeat words or simply use minor variations of words (e.g., jump, jumping, jumper). Normative data are available for a number of letters, making the task ideal for the repeated within person testing used in the proposed research. Outcomes included 1) number of unique words generated in 1 minute, 2) number of rule violations, 3) number of switches (a measure executive function), and 4) cluster size (a measure of semantic memory) (Troyer, 2000).

Stroop task: This is a commonly used measure of selective attention and response inhibition (Stroop, 1935; MacLeod, 1991). In the task individuals will name the color of neutral stimuli (e.g., XXXX present in red) or incongruent stimuli (e.g., RED presented in blue). Seeing the word “RED” interferes with the naming response for “blue” resulting in slower response time and increased errors for incongruent stimuli relative to neutral stimuli. The Stroop task is highly sensitive to individual differences, as well as, state variables such as negative affect and stress; the effect is maintained with extensive practice making it suitable for a study requiring multiple within subject measurement. In the task, individual named the color of 40 stimuli presented on a card. Outcomes include 1-2) the time required to complete neutral and incongruent cards, 3) the difference in naming time between the incongruent and neutral card (a measure of inhibitory control), and 4) naming errors for the incongruent card.

Speed of processing: The pattern comparison task (Salthouse, 1992) was used to measure speed of processing. In the task individuals viewed strings of letters and digits (e.g., XO3A ___ XO3A or X23A) and decide whether or not the two strings are identical. For each point of measurement, individuals completed 20 comparisons including 10 match trials and 10 non-match trials. Outcomes included 1) the time required to complete 20 decision, and 2) the number of errors.

Statistical analysis

Means and standard deviations were calculated for all study variables. The main effect of protein (no animal protein, low and high) on each outcome measure was assessed using a repeated measures mixed effects model. Baseline values were used as a covariate in the model. Statistical significance was set at $p < 0.05$, two-tailed. Statistical analysis was conducted using SPSS for windows (version 16.0; SPSS, Chicago, IL, USA). Based on a recently completed study using a similar design, a sample size of 28 was estimated to be sufficient to detect a difference of 10% in food intake, subjective appetite and physiological markers of appetite using an alpha level of .05, and a desired power of .80. Thirty three participants will be recruited to allow for attrition. The PI will conducted the statistical analysis of the study data. The treatment sessions will be coded and not revealed until after analysis is complete to reduce the risk of bias.

Results

Participant characteristics

Nineteen males and 14 females completed the study. The mean age was 21 (SD = 2) and the mean body mass index was 23.4 (SD = 1.7).

Food intake

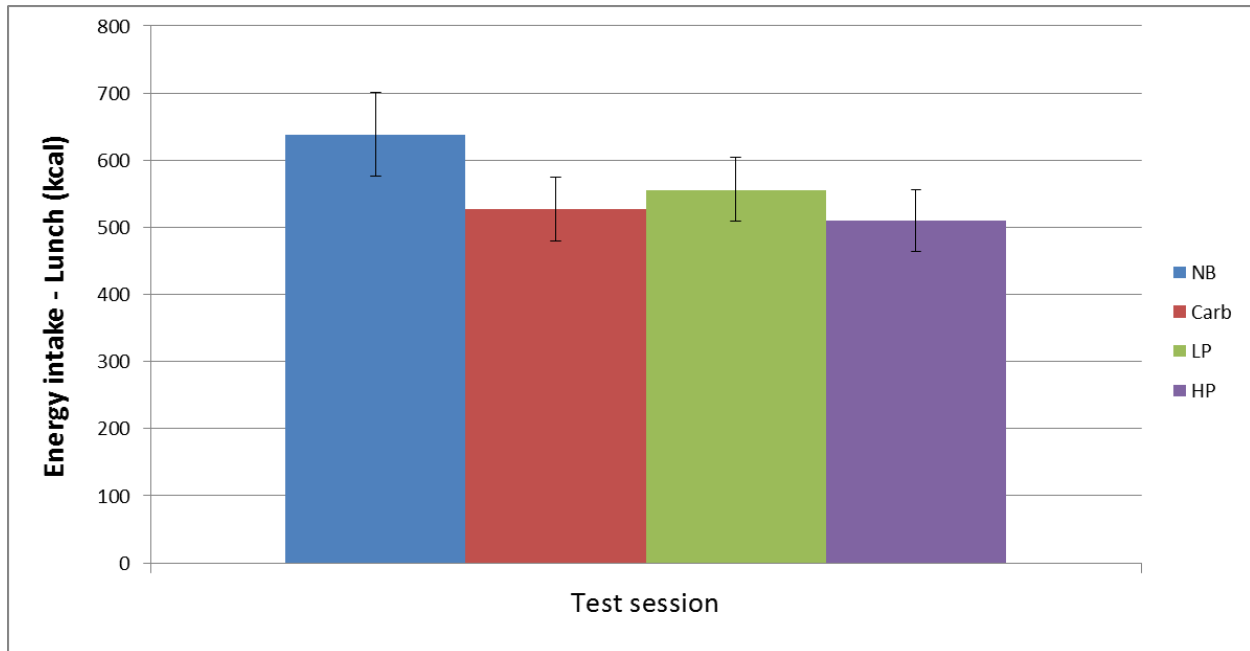


Figure one – food intake at the lunch meal

Figure one illustrates food intake at the lunch meal following the four different breakfast meals. There was a significant main effect of breakfast on food intake at lunch ($F_{3,96} = 4.680$; $p < 0.05$). A post hoc analysis revealed that food intake at lunch was higher following the no breakfast condition compared to the CHO and HP condition ($p < 0.05$). There was no statistically significant difference between the CHO, LP or HP conditions.

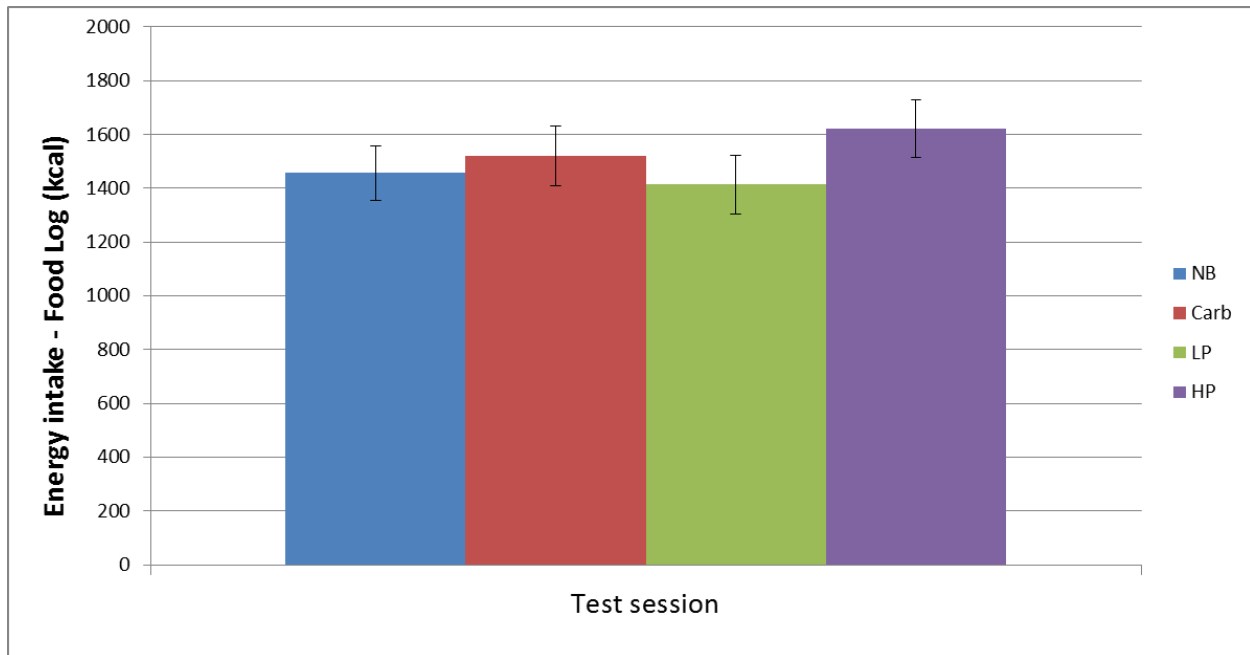


Figure two – food intake outside of the laboratory

Figure two illustrates food intake following the lunch meal meal following the four different breakfast meals. There was no statistically significant main effect of breakfast type on food intake outside of the laboratory ($F(3,96)=1.069;p=0.363$).

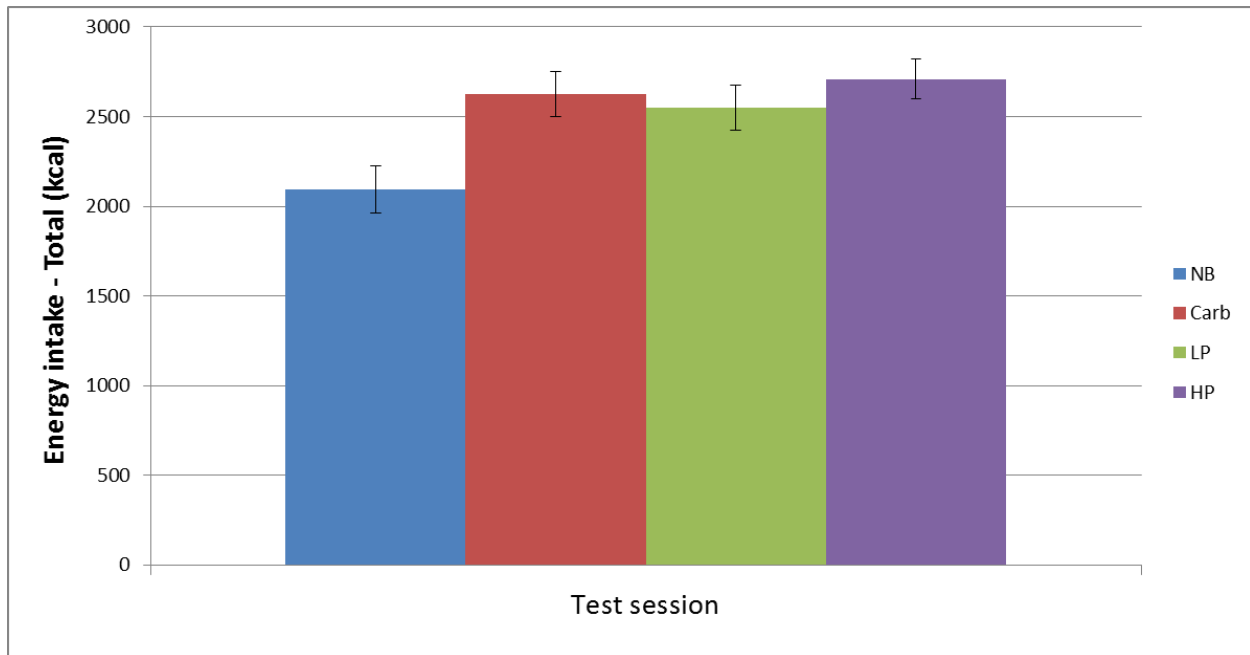


Figure three – total food intake over the test day

Figure two illustrates food intake following the lunch meal following the four different breakfast meals. There was a statistically significant main effect of breakfast type on food intake ($F(3,96)=8.920;p<0.05$). Post hoc analysis revealed that total daily food intake was lower on the day that participants consumed no breakfast compared to the other test sessions ($p<0.05$). There was no statistically significant difference between the three test sessions when breakfast was consumed.

Appetite data

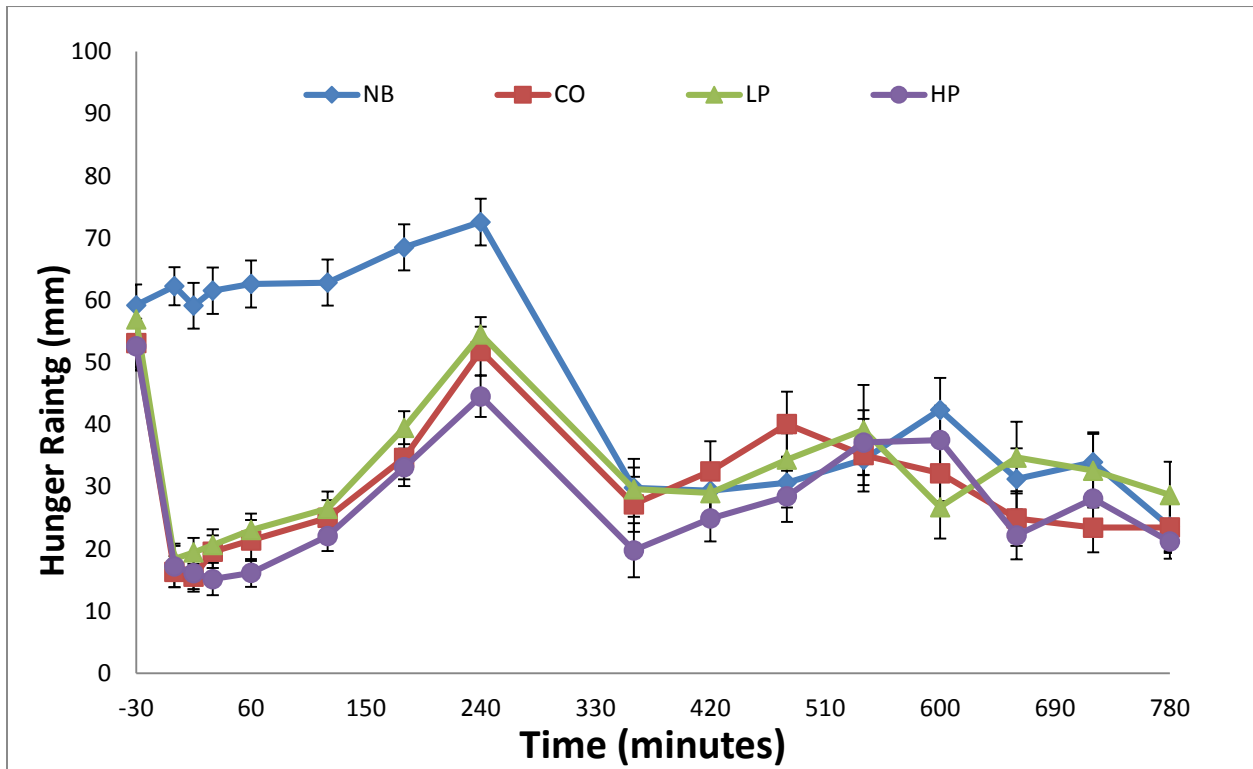


Figure four – hunger ratings during the test day. A questionnaire that captured appetite sensations was collected at regular intervals over 780 minutes.

Figure four illustrates subjective hunger ratings throughout each test day. When the participants were in the laboratory (-30 to 240 minutes) there was a statistically significant main effect of breakfast type on hunger ($F(3,154)=127.7;p<0.05$). Post hoc analysis revealed that subjective hunger was higher following the NB condition ($p<0.05$) but there was no statistically significant difference between the three test sessions when breakfast was consumed.

Following the lunch meal (served at 0 + 240 minutes), participants left the laboratory and the mean hunger rating was calculated for this period. There was no statistically significant effect of breakfast on hunger ratings during this period ($F(3, 102) =1.081, p>0.05$).

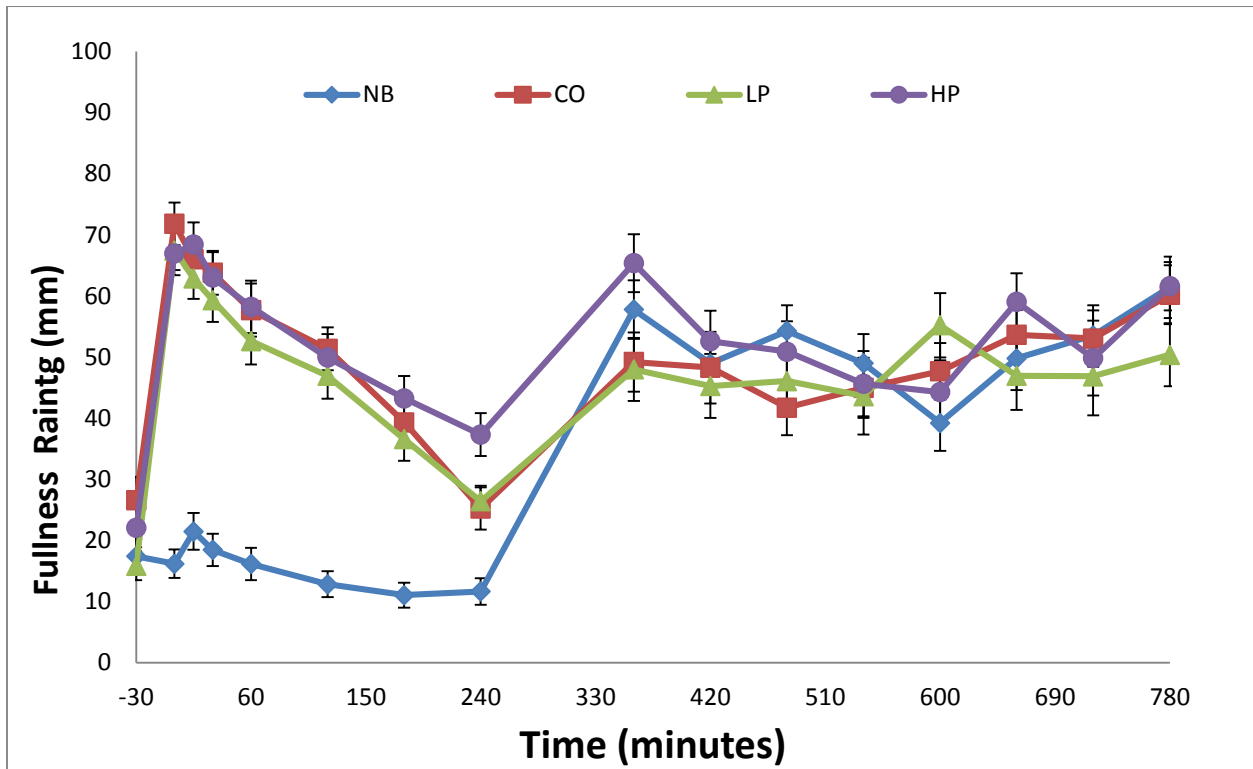


Figure five – fullness ratings during the test day. A questionnaire that captured appetite sensations was collected at regular intervals over 780 minutes.

Figure five illustrates subjective fullness ratings throughout each test day. When the participants were in the laboratory (-30 to 240 minutes) there was a statistically significant main effect of breakfast type on fullness ($F(3,137)=24.7;p<0.05$). Post hoc analysis revealed that subjective fullness was lower following the NB condition ($p<0.05$) but there was no statistically significant difference between the three test sessions when breakfast was consumed.

Following the lunch meal (served at 0 + 240 minutes), participants left the laboratory and the mean fullness rating was calculated for this period. There was no statistically significant effect of breakfast on fullness ratings during this period ($F(3, 102) = 1.278, p>0.05$).

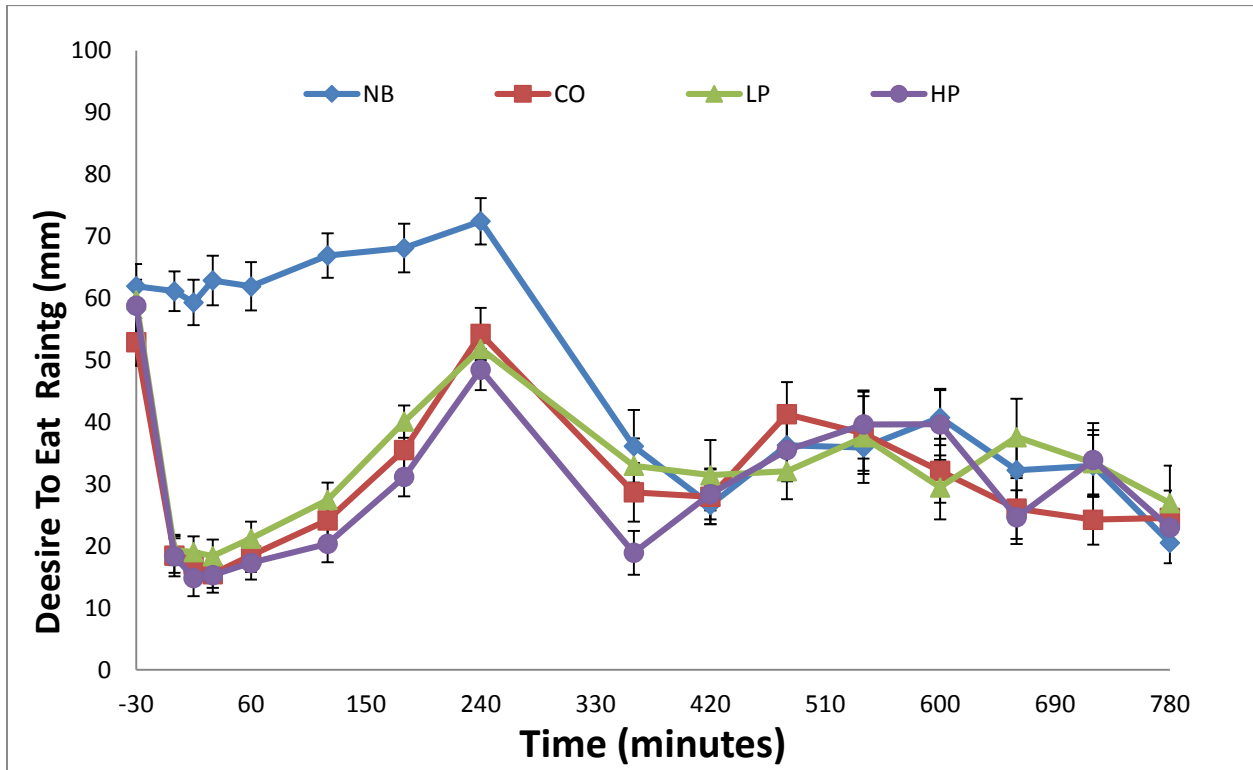


Figure six – desire to eat ratings during the test day. A questionnaire that captured appetite sensations was collected at regular intervals over 780 minutes.

Figure six illustrates subjective desire to eat ratings throughout each test day. When the participants were in the laboratory (-30 – 240 minutes) there was a statistically significant main effect of breakfast type on desire to eat ($F(3,134)=23.1;p<0.05$). Post hoc analysis revealed that subjective fullness was lower following the NB condition ($p<0.05$) but there was no statistically significant difference between the three test sessions when breakfast was consumed.

Following the lunch meal (served at 0 + 240 minutes), participants left the laboratory and the mean desire to eat rating was calculated for this period. There was no statistically significant effect of breakfast on desire to eat ratings during this period ($F(3, 102) = 0.283, p > 0.05$).

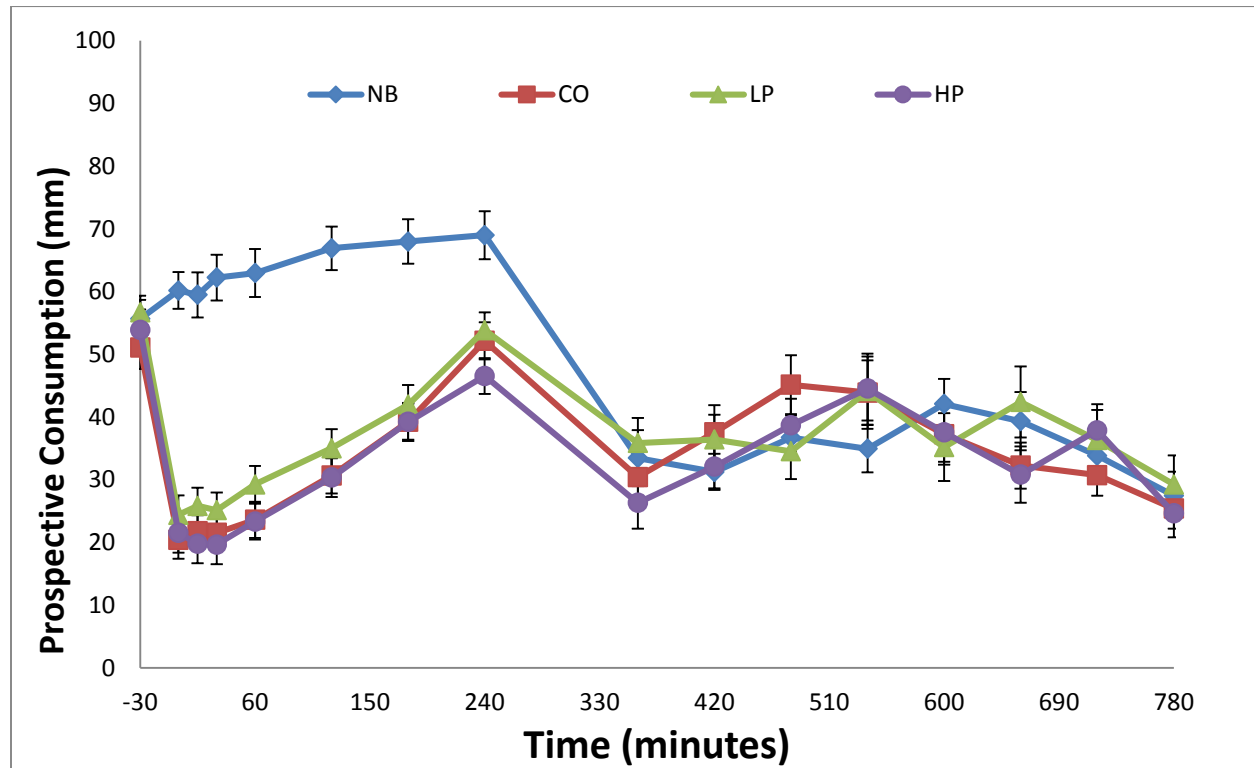


Figure seven – prospective consumption ratings during the test day. A questionnaire that captured appetite sensations was collected at regular intervals over 780 minutes.

Figure seven illustrates subjective desire to eat ratings throughout each test day. When the participants were in the laboratory (-30 – 240 minutes) there was a statistically significant main effect of breakfast type on prospective consumption ($F(3,131)=20.1;p<0.05$). Post hoc analysis revealed that subjective prospective consumption was lower following the NB condition ($p<0.05$) but there was no statistically significant difference between the three test sessions when breakfast was consumed.

Following the lunch meal (served at 0 + 240 minutes), participants left the laboratory and the mean prospective consumption rating was calculated for this period. There was no statistically significant effect of breakfast on desire to eat ratings during this period ($F(3, 102) = 0.277$, $p > 0.05$).

Insulin data

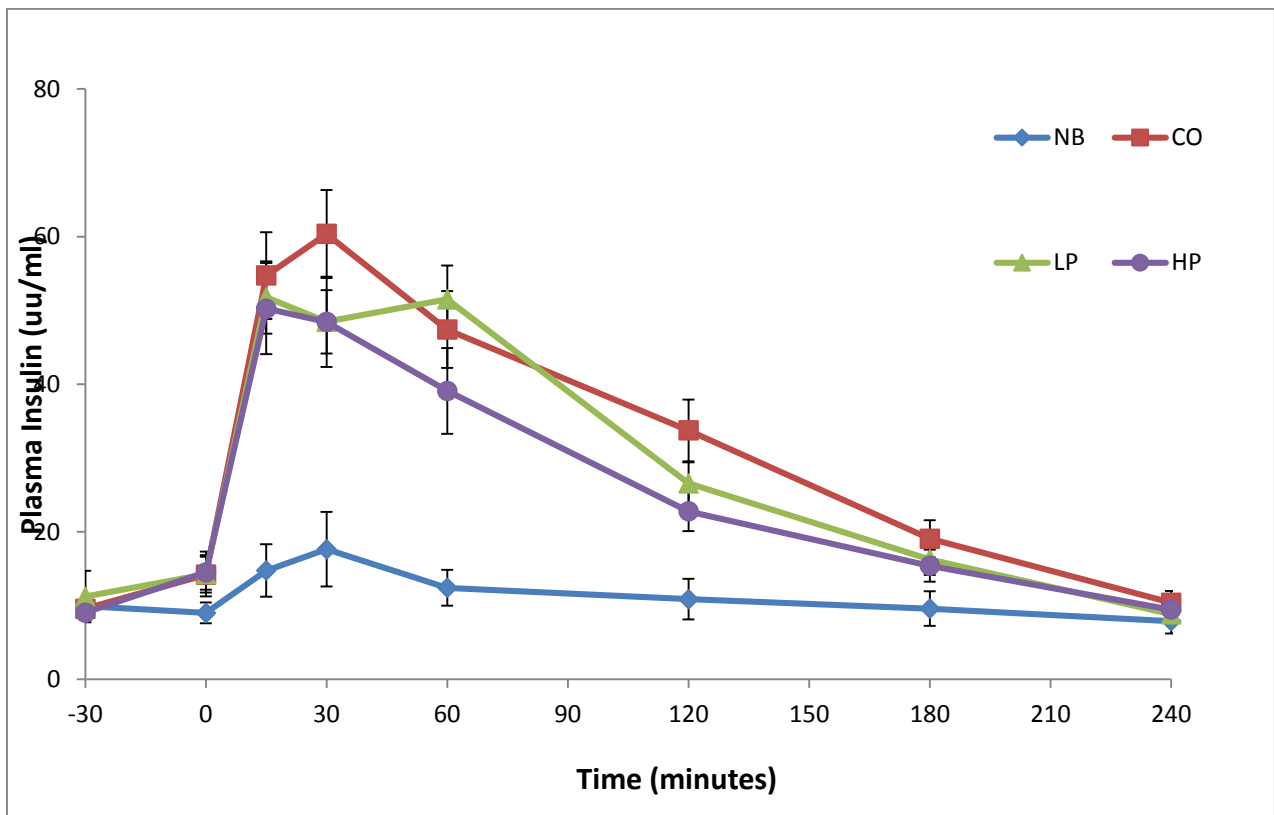


Figure eight – Plasma insulin concentration during the test session

Figure eight illustrates the plasma insulin concentration during the test session. There was a statistically significant main effect of breakfast type on the plasma concentration of insulin ($F(3, 169) = 28.395$; $p < 0.05$). Post hoc analysis revealed that plasma insulin concentration was lower

following the NB condition ($p < 0.05$) but there was no statistically significant difference between the three test sessions when breakfast was consumed.

Glucose data

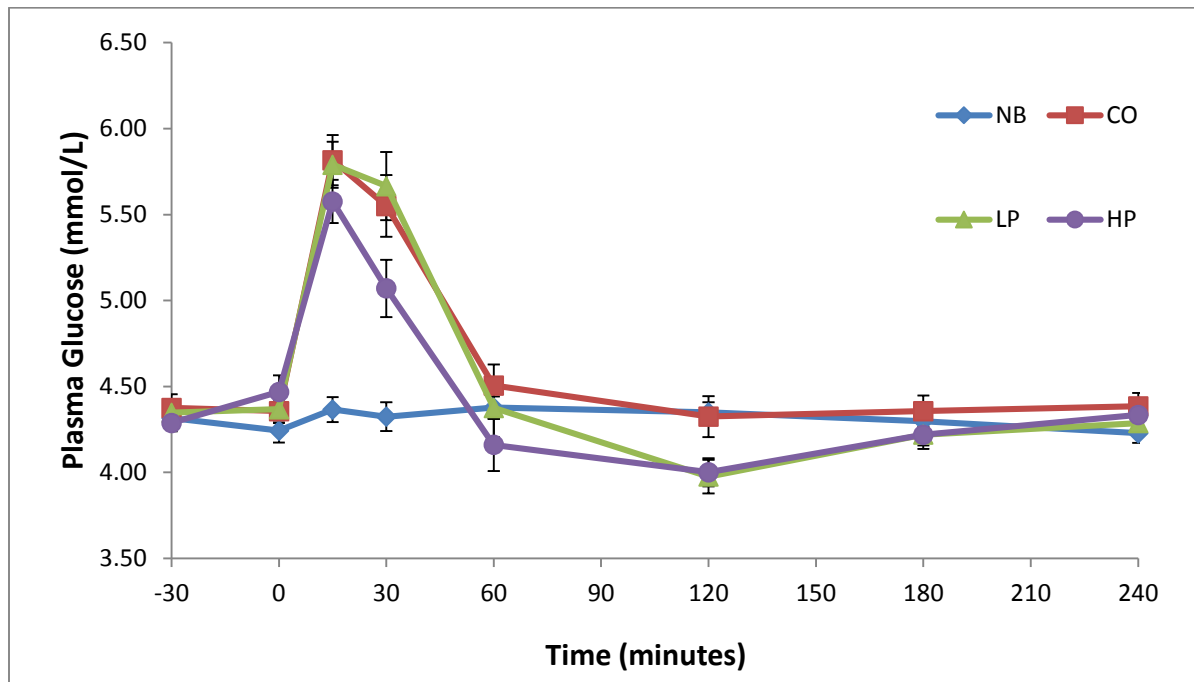


Figure nine – Plasma glucose concentration during the test session

Figure eight illustrates the plasma glucose concentration during the test session. There was a statistically significant main effect of breakfast type on the plasma concentration of glucose ($F(3, 9.412) = 23.444$; $p < 0.05$). Post hoc analysis revealed that plasma glucose concentration was lower following the NB condition ($p < 0.05$) but there was no statistically significant difference between the three test sessions when breakfast was consumed.

Cognition data

Affect scale

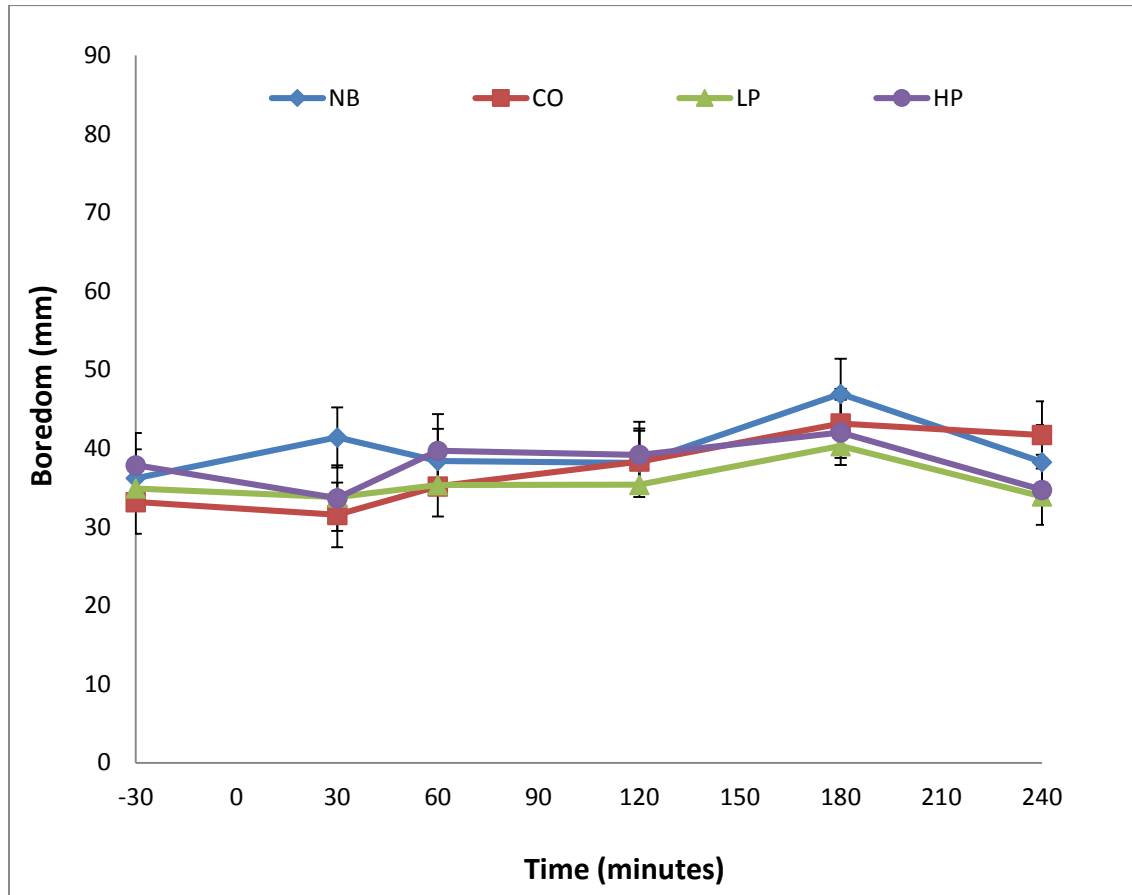


Figure ten – participants' feelings of boredom during the test session

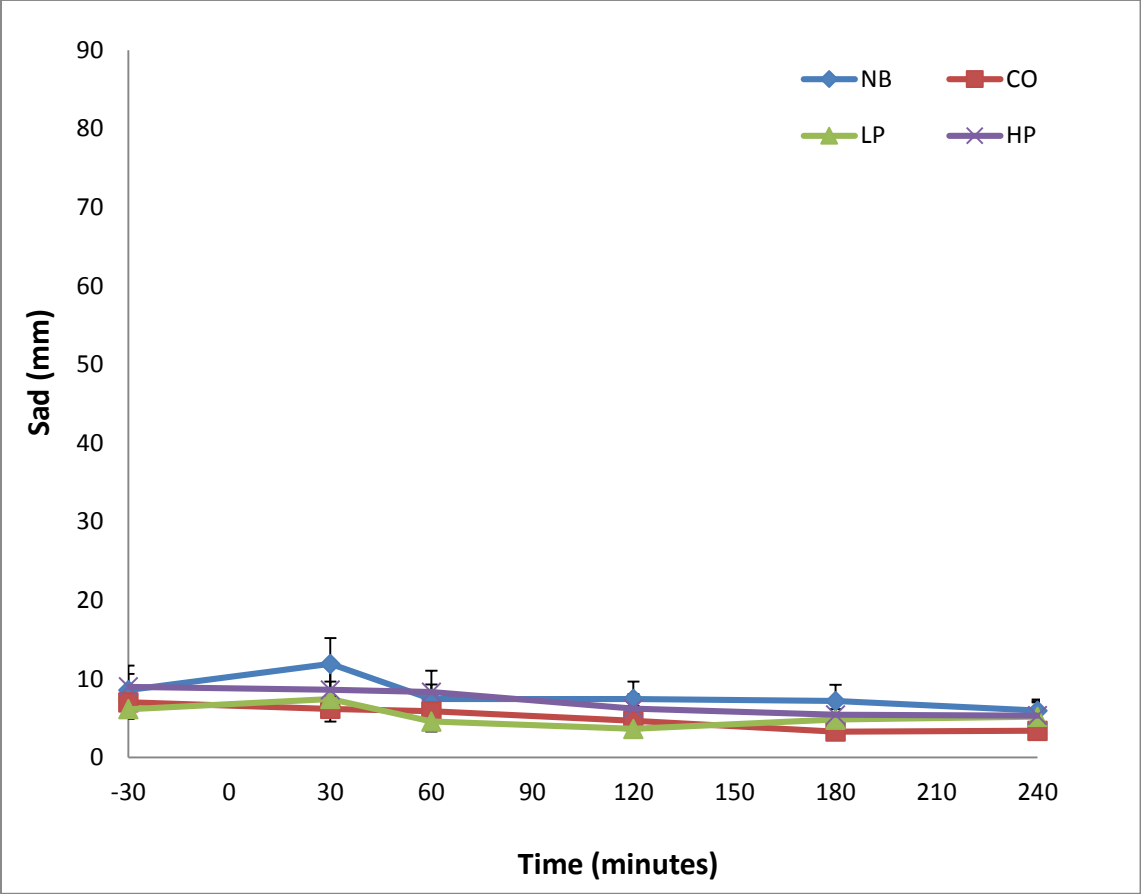


Figure eleven – participants' feelings of sadness during the test session

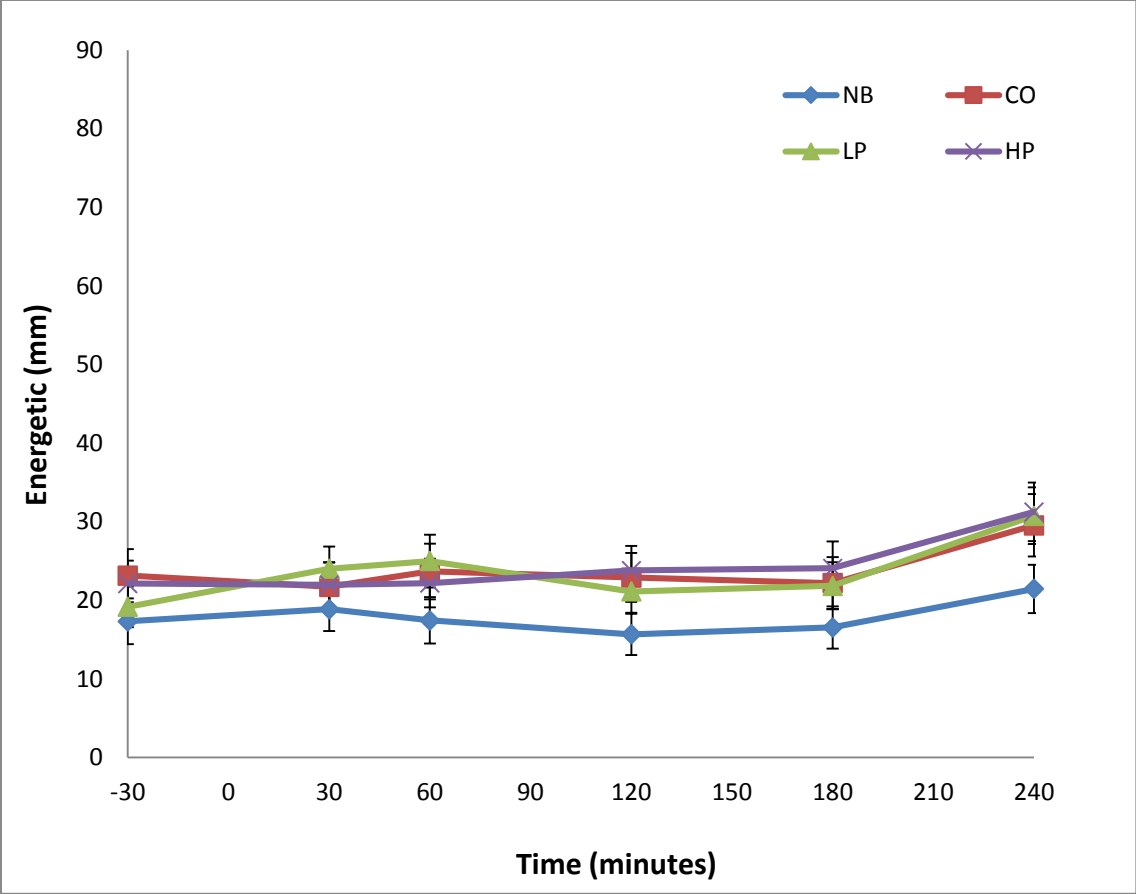


Figure twelve – participants' feelings of energy during the test session

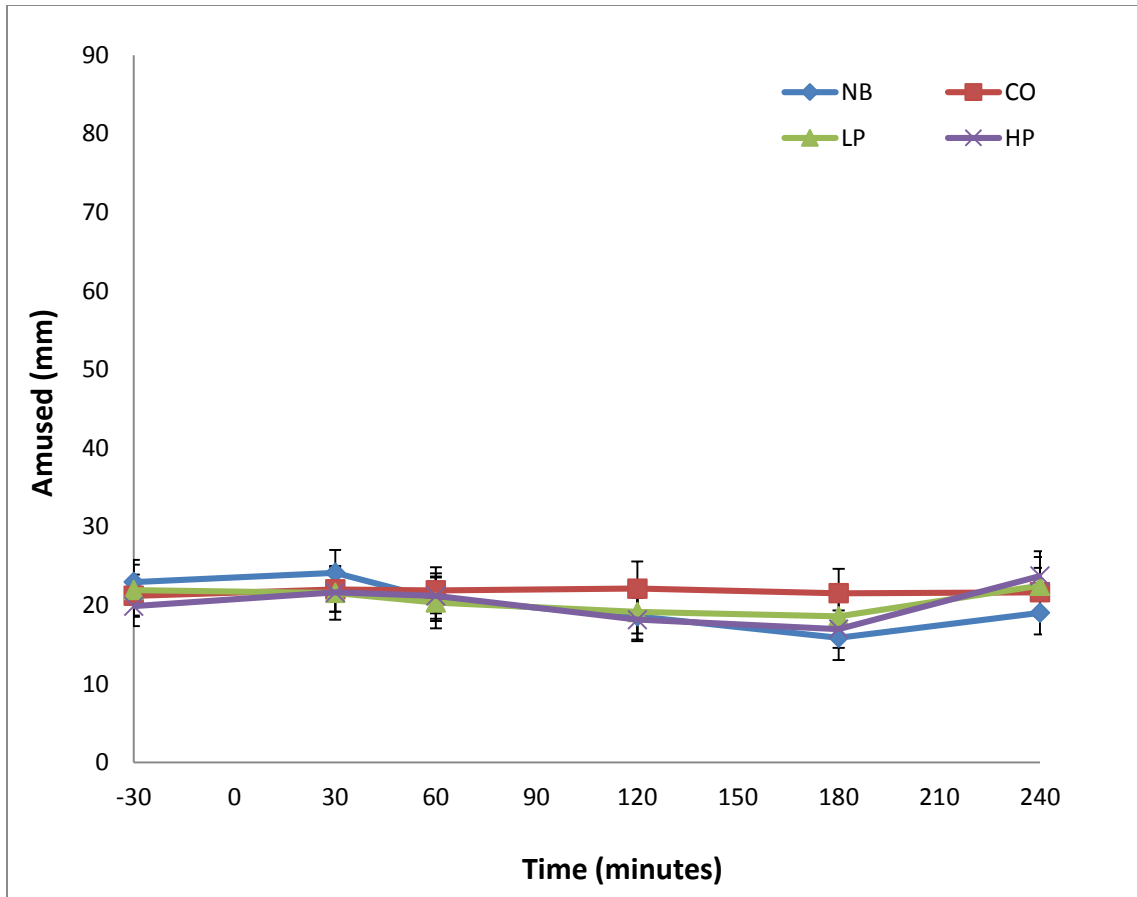


Figure thirteen – participants' feelings of amusement during the test session

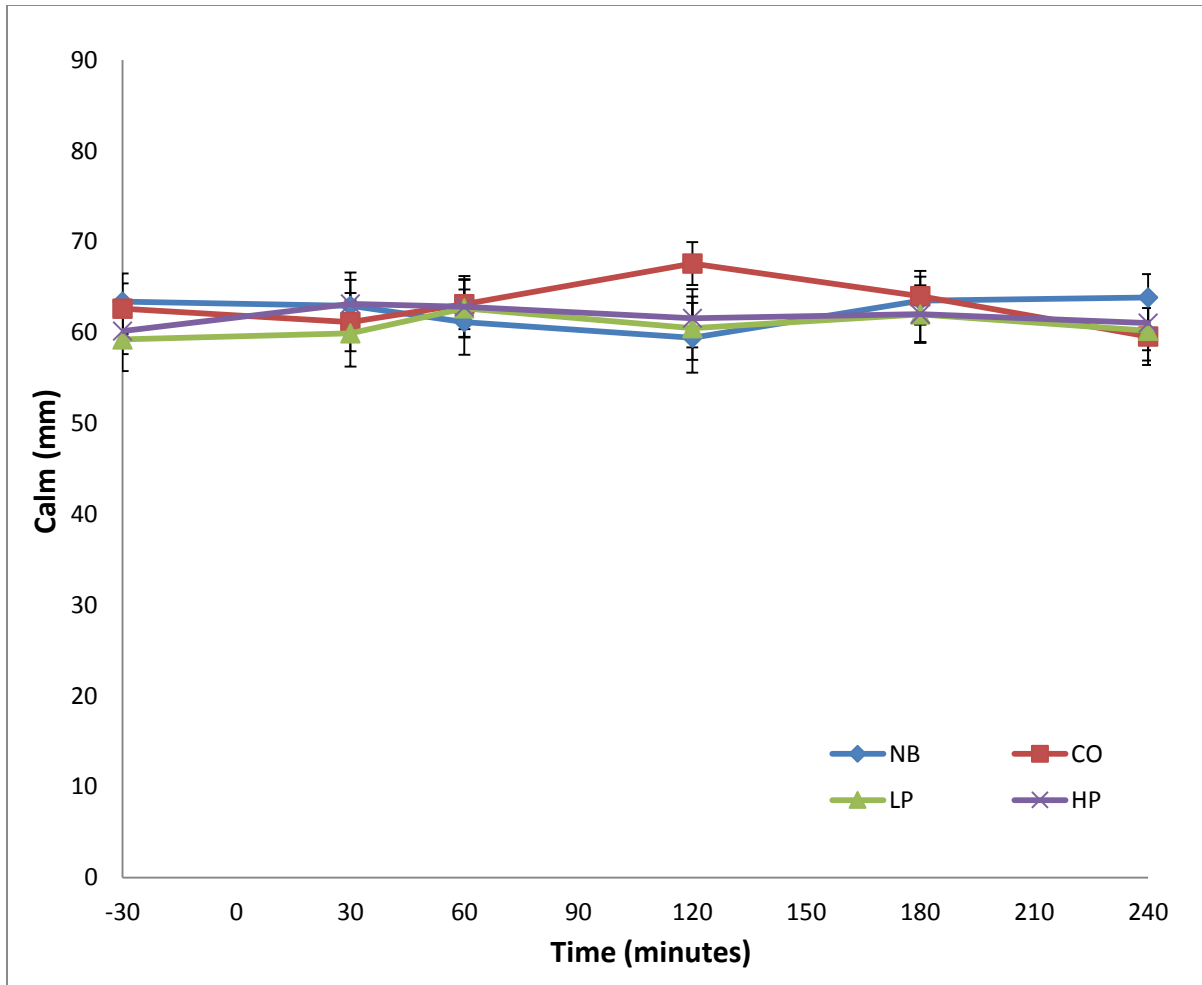


Figure fourteen – participants' feelings of calm during the test session

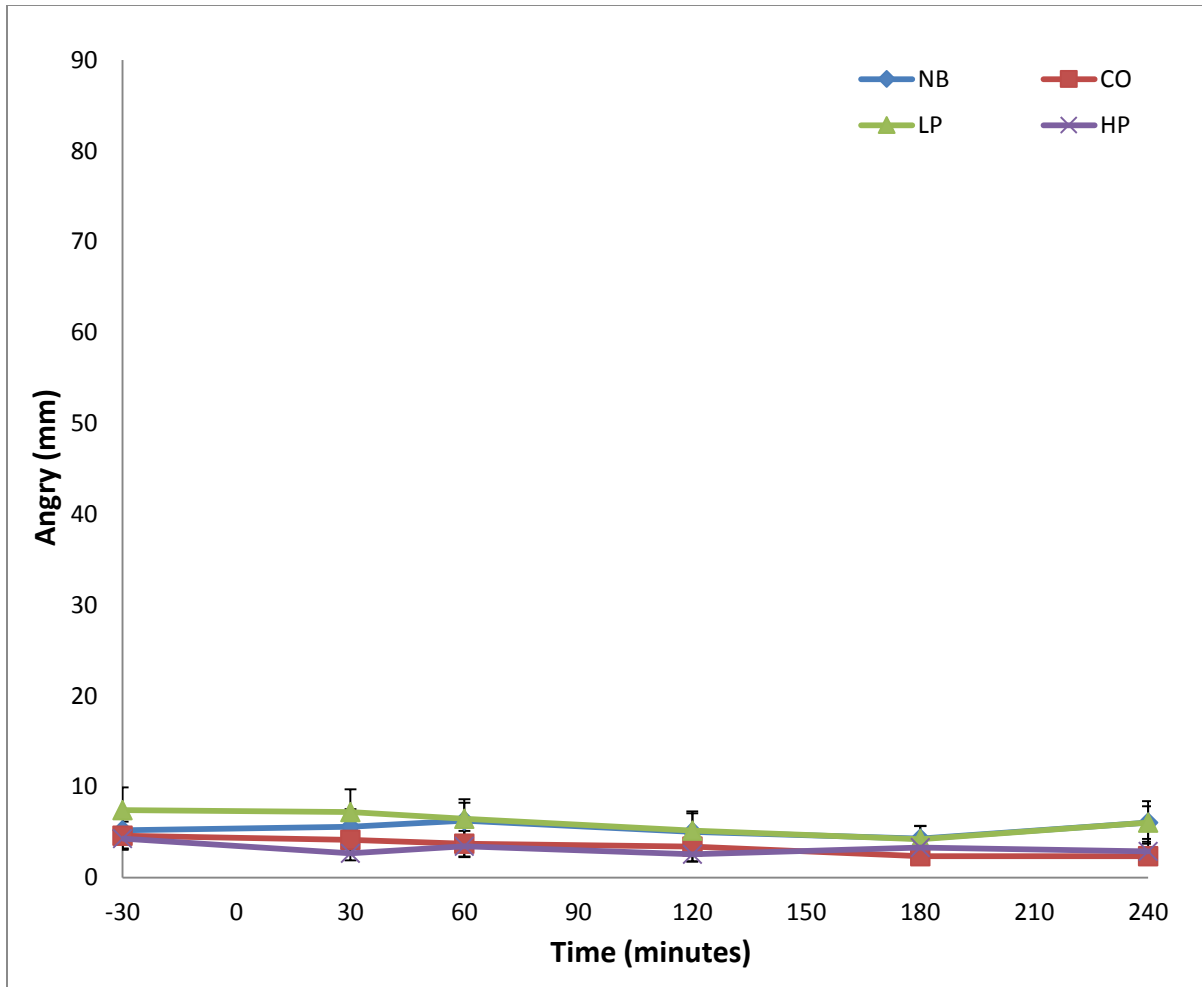


Figure fifteen – participants' feelings of anger during the test session

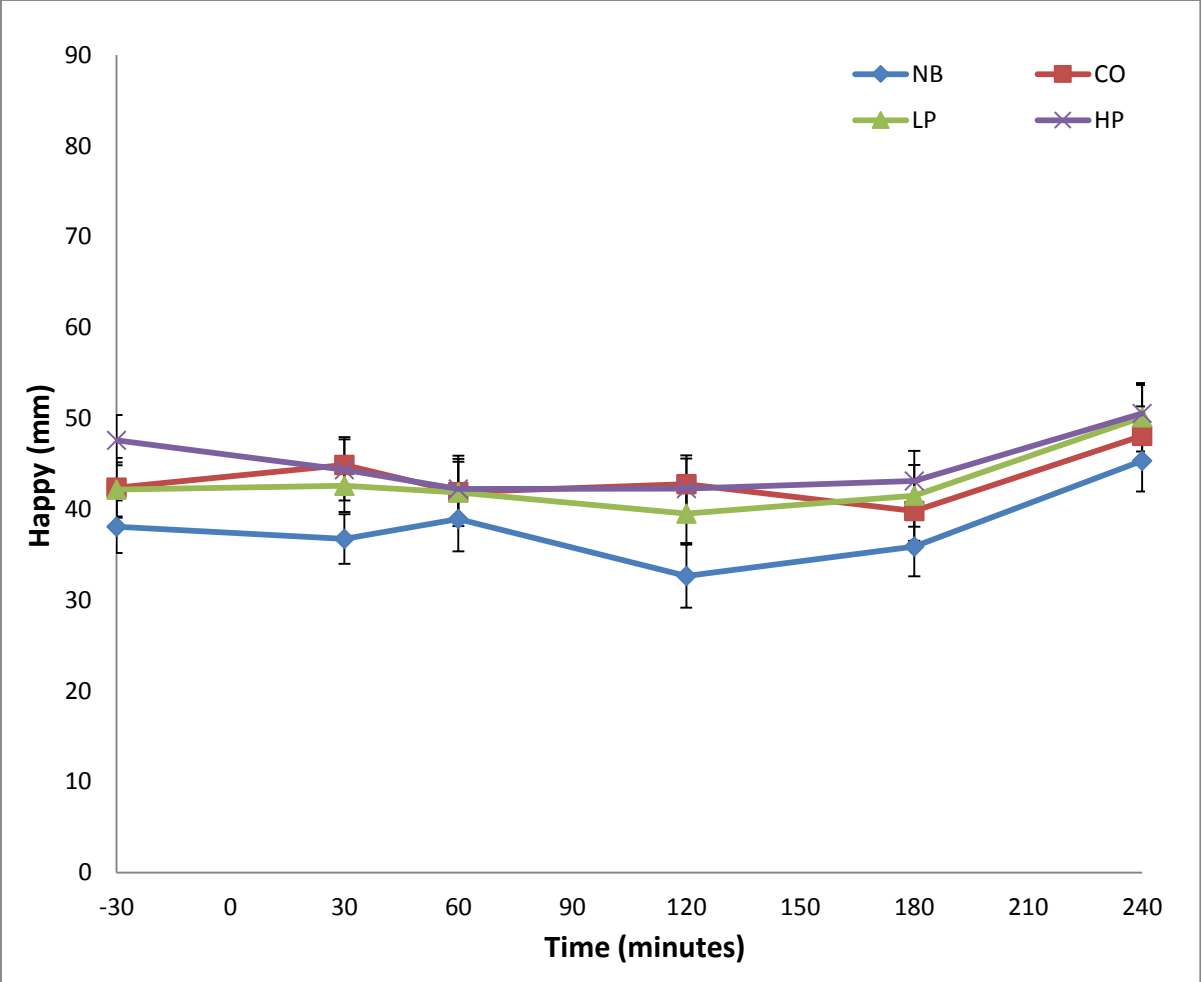


Figure sixteen – participants' feelings of happiness during the test session

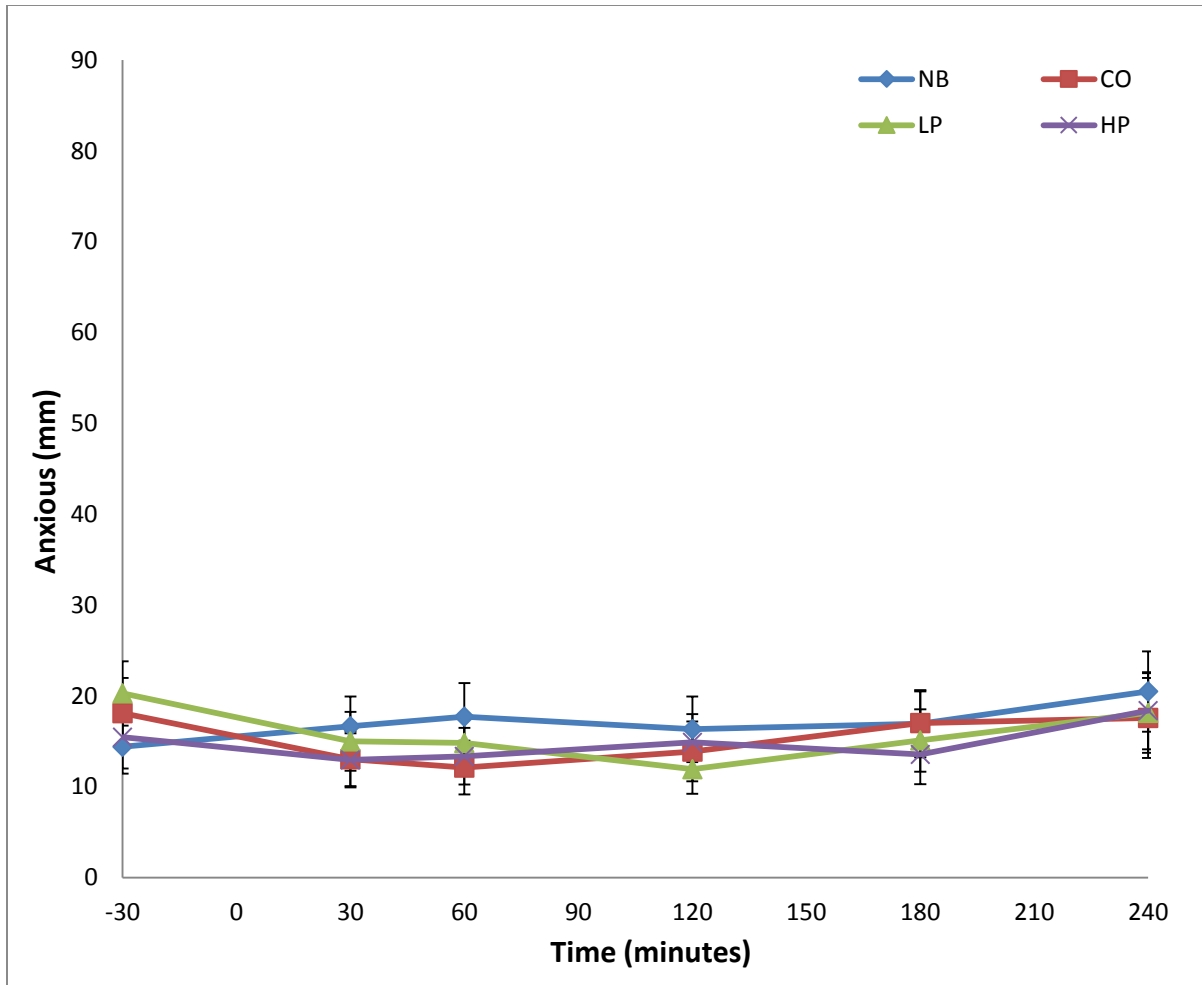


Figure seventeen – participants' feelings of anxiousness during the test session

Figure 10 -17 illustrate the results from the affect scale. There was no statistically significant effect of breakfast on any of the measures.

Stroop test

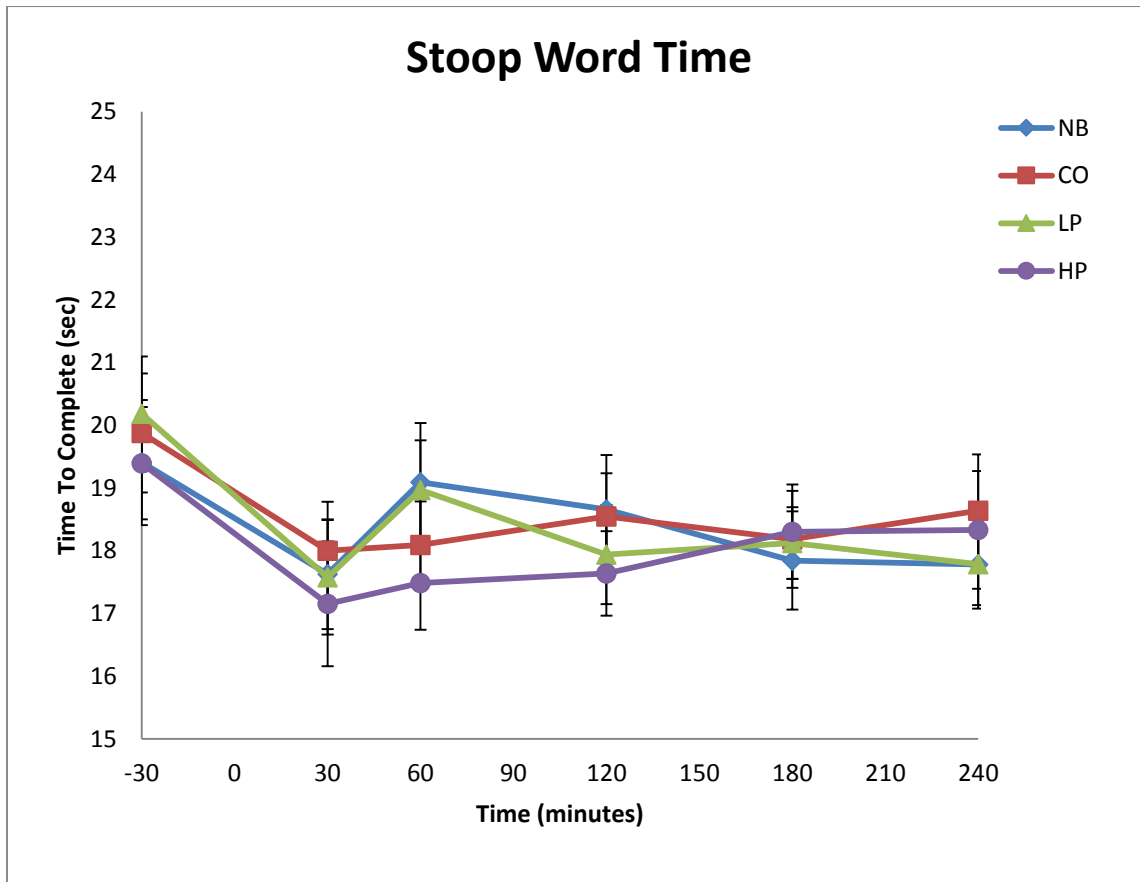


Figure eighteen – Time taken to complete the Stroop test at each timepoint

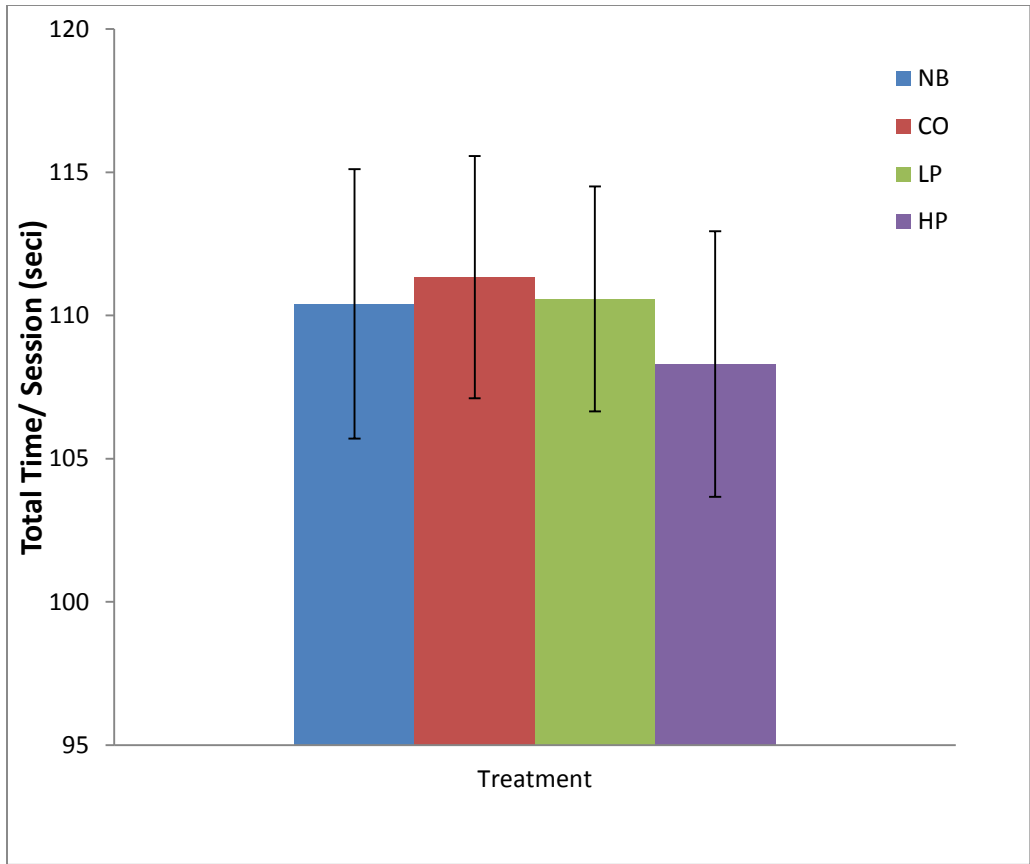


Figure nineteen – Time taken to complete the Stroop test during the test session

Figure 18 and 19 illustrate the results from the Stroop test. For the XX task the 2-way interaction was not statistically significant. For the Incongruent Word trials the 2-way interaction is not significant. The Stroop effect (Incongruent > XX) appears to be fairly stable across measurements and insensitive to breakfast.

Comparison test

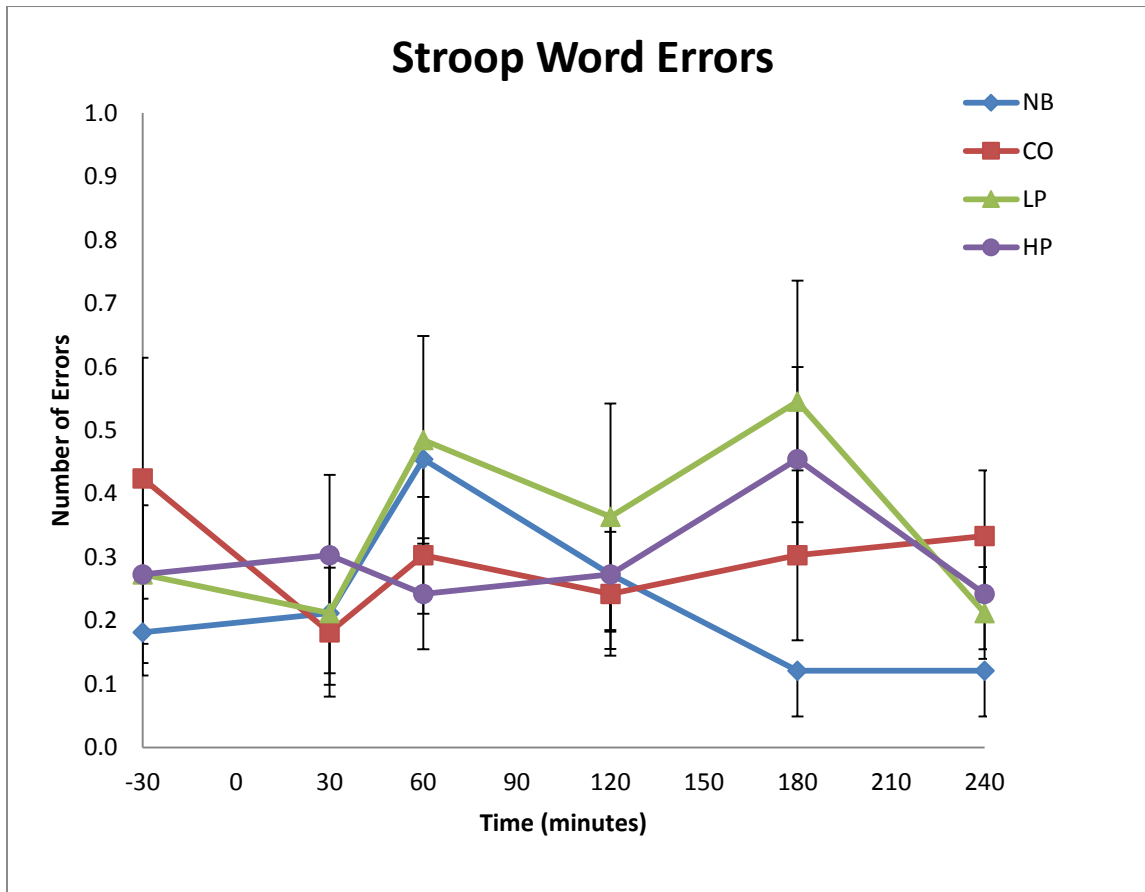


Figure twenty – number of errors made at each timepoint while completing the comparison test

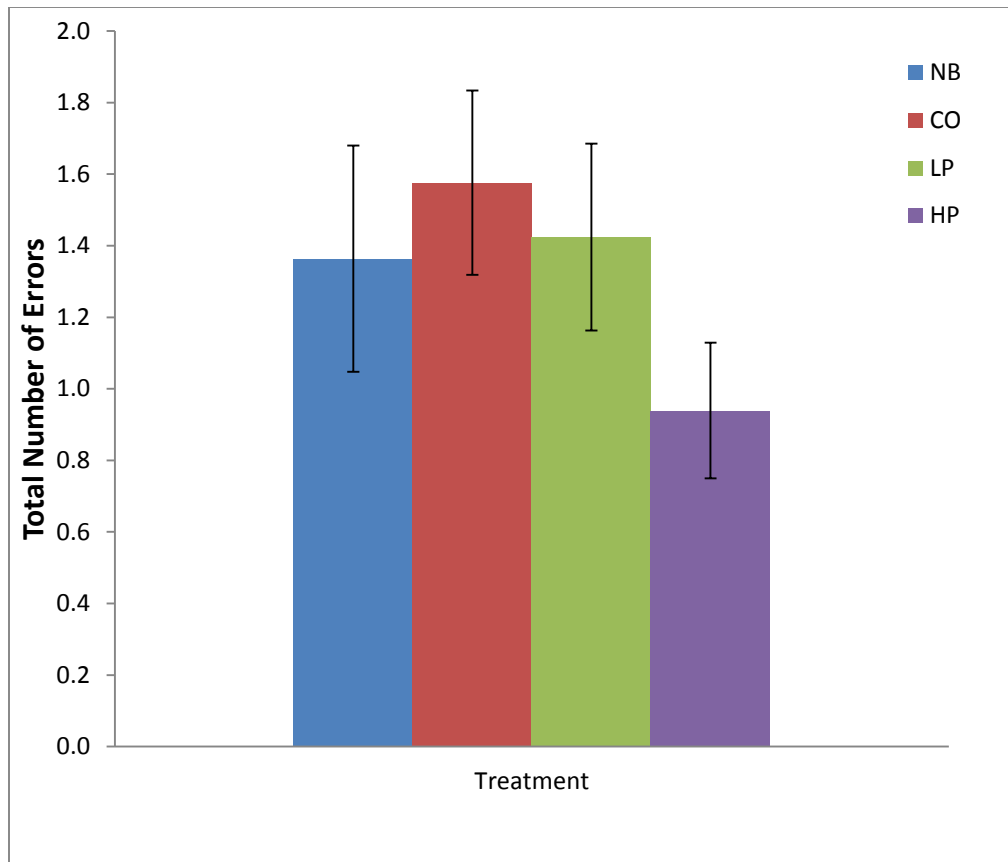


Figure twenty one – number of errors made while completing the comparison test

Figure 20 and 21 illustrate the results of the comparison test. Figure 20 and 21 illustrate the results of the comparison test. Following the high protein breakfast there was a reduction in the number of errors made in the comparison test ($p < 0.05$). However, there was no statistically significant differences between the other breakfast meals.

List Learning Task:

List 1: Time x Breakfast interact ($p = .035$), from the t-tests for the change scores using $p = .001$ nothing really stands out other than 240 minutes have a larger change than other measurements – this might be considered a measure of primary or short-term memory. List 2: The Time x Breakfast interaction is not significant ($p = .346$), from the t-test it looks like No Breakfast leads to

poorer performance later in testing and this might be true for No Breakfast earlier than for the other three. – This might indicate that any breakfast has a somewhat protective effect against interference in short-term memory

Delay Recall: The Time x Breakfast interaction is not significant ($p = .114$), from the t-tests it looks like HP might be somewhat protective over the first 60 minutes (i.e., p values $>.44$ in contrast to other others that are much lower).

Fluency Task:

Fluency improves over time and there is a trend for the high protein breakfast to result in higher fluency (multivariate test $p = .061$).

Discussion

This study found that increasing the protein content of breakfast using pork reduced food intake at the lunch meal. However, over the total day there was no effect of the different breakfast meals on food intake. Indeed, not consuming breakfast resulted in a lower total food intake. While skipping breakfast resulted in higher hunger, desire to eat, prospective consumption and lower fullness before lunch these differences disappeared after the lunch meal and there was no differences between the different breakfast meals. There were some modest effects of breakfast composition on cognitive performance which favored the high protein breakfast.

While several studies have reported an effect of protein consumption on appetite and food intake this present study failed to support the hypothesis that increasing protein consumption promotes satiety. It is not clear why this is the case although it is possible that the amount of protein

consumed was not sufficient to meet a threshold for an effect on appetite. Further research is required to determine if there is threshold quantity of protein that is required to be consumed before there is an effect on appetite.

The effect of breakfast consumption or the protein content of breakfast was modest. Where differences were apparent there was insufficient statistical power to obtain a statistically significant result. Larger studies are required to adequately determine the effect of breakfast and protein consumption on cognitive performance.

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