# First and second meal effects of pulses on blood glucose, appetite, and food intake at a later meal

**Rebecca C. Mollard, Christina L. Wong, Bohdan L. Luhovyy, and G. Harvey Anderson**



**Abstract:** Pulses are low-glycemic appetite-suppressing foods, but it is not known whether these properties persist after being consumed as part of a meal and after a second meal. The objective of this study was to determine the effects of a fixed-size pulse meal on appetite and blood glucose (BG) before and after an ad libitum test meal (pizza) and on food intake (FI) at the test meal. Males ($n$ = 25; 21.3 ± 0.5 years; 21.6 ± 0.3 kg·m$^{-2}$) randomly consumed 4 isocaloric meals: chickpea; lentil; yellow split pea; and macaroni and cheese (control). Commercially available canned pulses provided 250 kcal, and were consumed with macaroni and tomato sauce. FI was measured at a pizza meal 260 min after consumption of the isocaloric meal. BG and appetite were measured from 0 to 340 min. The lentil and yellow pea, but not chickpea, treatments led to lower appetite ratings during the 260 min prepizza meal period, and less FI at the pizza meal, compared with macaroni and cheese ($p < 0.05$). All pulse treatments lowered BG immediately following consumption (at 20 min) ($p < 0.05$), but there was no effect of treatment on prepizza meal BG AUC ($p = 0.07$). Immediately after the pizza meal, BG was lower following the chickpea and lentil treatments, but not the yellow pea treatment ($p < 0.05$). Postpizza meal BG AUC was lower following the chickpea and lentil treatments than in the yellow pea treatment ($p < 0.05$). The beneficial effects of consuming a pulse meal on appetite, FI at a later meal, and the BG response to a later meal are dependent on pulse type.

*Key words:* whole pulses, blood glucose, appetite, food intake, mixed meal.

**Résumé :** Les légumineuses sont des aliments coupe-faim à faible glycémie; néanmoins, on ne sait pas si ces propriétés persistent quand on consomme ces aliments au cours d'un repas ou à la suite d'un premier repas. Cette étude se propose d'évaluer les effets d'un repas donné contenant des légumineuses sur l'appétit et le taux de glucose sanguin (BG) avant et après un repas d'épreuve ad libitum et sur l'apport alimentaire (FI) au cours du repas d'épreuve. Des hommes ($n$ = 25, 21,3 ± 0,5 ans, 21,6 ± 0,3 kg·m$^{-2}$) répartis aléatoirement prennent quatre plats isoénergétiques : de pois chiches, de lentilles, de pois cassés jaunes et de macaroni et de fromage (contrôle). Les sujets consomment des légumineuses en conserve en vente sur le marché contenant 250 kcal et servies avec du macaroni et de la sauce tomate. On évalue FI au cours de la consommation d'un plat de pizza 260 min plus tard. On évalue le BG et l'appétit de la première à la 340$^{e}$ minute. Les plats de lentilles et de pois jaunes, mais pas le plat de pois chiches, suscitent des degrés d'appétit inférieurs au cours des 260 min précédant le plat de pizza et diminuent le FI au repas d'épreuve, comparativement au plat de macaroni et fromage ($p < 0,05$). À la suite de l'apport alimentaire, tous les plats de légumineuses abaissent le BG à la 20$^{e}$ minute ($p < 0,05$), mais ces plats n'ont aucun effet sur la surface sous la courbe (AUC) de BG précédant le plat de pizza ($p = 0,07$). Tout de suite après le plat de pizza, on observe un plus faible taux de BG après avoir pris les plats de pois chiches et de lentilles, mais pas après le plat de pois jaunes ($p < 0,05$). La surface sous la courbe de BG consécutive au plat de pizza est plus faible après avoir consommé des pois chiches et des lentilles qu'après avoir consommé de pois cassés ($p < 0,05$). Les effets bénéfiques d'un plat de légumineuses sur l'appétit, l'apport alimentaire et le taux de glucose sanguin consécutif à un repas ultérieur dépendent du type de légumineuses.

*Mots-clés :* légumineuses entières, glucose sanguin, appétit, apport alimentaire, repas mixte.

[Traduit par la Rédaction]

## Introduction

Pulses are the edible seeds of legumes or pod-bearing plants, and include beans, chickpeas, yellow peas, and lentils. Regular consumption of pulses (half a cup per day) is related to higher-quality diets, including higher intakes of fiber, protein, folate, zinc, iron, and magnesium, and lower intakes of saturated fat and total fat (Mitchell et al. 2009). Pulse consumption, alone (Papanikolaou and Fulgoni 2008) or included in a dietary pattern (Sichieri 2002; Newby et al. 2004; Roberts et al. 2005), is associated, in epidemiologic studies, with reduced body weight, waist circumference, and risk of overweight and obesity.

Short-term studies have shown that pulses have a low glycemic index (GI) (Jenkins et al. 1980; Nestel et al. 2004;

Received 29 January 2011. Accepted 27 May 2011. Published at www.nrcresearchpress.com/apnm on 29 September 2011.

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Wong et al. 2009) and suppress appetite (Wong et al. 2009). Lower blood glucose (BG) and decreased appetite have been reported following the consumption of 1.5 to 2.0 cups of pulses alone, compared with white bread (Wong et al. 2009). In addition, lower BG response was found, not only after a breakfast of predominately lentils with butter and tomatoes (compared with whole-meal bread with cottage cheese and tomatoes), but also after a standardized meal 4 h later (Jenkins et al. 1982). This effect on postprandial BG response following a later meal has been termed the "second meal effect" (Wolever et al. 1988), and it has been proposed that it occurs in response to the lente carbohydrate features of low-GI foods (Jenkins et al. 1982; Liljeberg et al. 1999; Nilsson et al. 2008). Colonic fermentation of indigestible carbohydrate (Brighenti et al. 2006) and slowing of gastric emptying (Hlebowicz et al. 2007) are 2 factors, independent from GI, that contribute to the second meal effect of foods. Thus, it can be speculated that not all low-GI foods have an effect on the postprandial BG response following a later meal.

Pulses are most commonly consumed with high-carbohydrate foods, such as rice, pasta, and bread, as a meal; however, it is currently not known how this affects their glycemic and appetite-suppressing properties. Therefore, the hypothesis of this study was that the consumption of a meal of pulses together with a high-GI carbohydrate will lower postprandial glycemic and appetite responses, not only following the meal, but also after a later meal, and will lower food intake (FI) at the later meal. Thus, the objective of this study was to determine the effect of lentils, chickpeas, and yellow peas consumed in meals of a fixed size on appetite and BG before and after an ad libitum test meal 4 h later, and on FI at the test meal (pizza), compared with a nonpulse meal.

## Materials and methods

### Subjects

Healthy males 20–30 years of age with a body mass index (BMI) of 20.0–24.9 kg·m$^{-2}$ were recruited through advertisements around the University of Toronto campus. Females, smokers, breakfast skippers, individuals with diabetes or other metabolic diseases, and those scoring ≥11 on an Eating Habit Questionnaire (Herman and Polivy 1980) were excluded from the study. Twenty-five subjects participated in the study. The sample size was determined, with a power analysis for a within-subject design from previous studies (Hamedani et al. 2009; Wong et al. 2009), to be sufficient to detect a treatment effect on FI of 150 kcal, with a power of 0.80 and an alpha of <0.05. Procedures were approved by the University of Toronto Health Sciences Research Ethics Board.

### Study design

Subjects were given one of the pulse treatments or the control treatment in a randomized order at weekly intervals. Nutritional composition details of the pulse and control treatments are presented in Table 1. Pulse treatments were chickpea (222.8 g of chickpeas, CanGro, Toronto, Ont., Canada), lentil (332.9 g of lentils, CanGro), and yellow pea (375.6 g of yellow peas, Nupak, Toronto, Ont., Canada). Pulses were commercially available canned products, and provided 250 kcal, or 42% of calories, in the treatments. The amount of pulses used was designed to provide an average of 40 g of available carbohydrate from each of the pulses (40% of available carbohydrate), and was equivalent to approximately 2 servings (1.5 to 2.0 cups), based on Canada's Food Guide. In addition, this was the amount provided in previous studies investigating the effects of pulses alone on BG, appetite, and FI control (Wong et al. 2009). Pulses were drained and rinsed under running water for 30 s. Pulses were consumed with macaroni pasta (64.5 g, Kraft Canada Inc., Don Mills, Ont., Canada) and tomato sauce (174.1 g, 220 mL). The tomato sauce was prepared on the premises, and contained diced tomatoes (195 g, President's Choice, Loblaws, Toronto, Ont.), garlic (2.2 g), onion (48.2 g), chili powder (1.0 g, Selection, Metro, Toronto, Ont., Canada), salt (0.9–1.3 g, Sifto Canada Inc., Mississauga, Ont., Canada), and canola oil (4.6 g, Canola Harvest, Richardson Oilseed Limited, Lethbridge, Alta., Canada). Added salt varied to account for differences in the amounts found in the canned pulses and to match palatability. Garlic and onions were bought fresh from a local supermarket. Pulse treatments were prepared as follows. Onions and garlic were cooked for 3 min over medium heat in canola oil, and then the additional tomato sauce ingredients (as listed above), water, and pulses were added. Water was added (22–150 mL) to account for differences in weight among the pulses so that they were matched for energy density. Once all the ingredients were added, the mixture was left to simmer on low heat for 20 min. The macaroni was cooked separately in boiling water for 8 min, and then drained. Pulse treatments were prepared the day before the session in our facilities, and reheated on high (100% power) for 2 min in a microwave oven (1200 W, Sharp Carousel R-310J, Romeoville, Ill., USA) immediately before serving. The control meal was macaroni and cheese, which was chosen because it is a commonly consumed, inexpensive, convenient, high-GI meal that provides an amount of available carbohydrates similar to pulses per calorie consumed. Macaroni and cheese included macaroni pasta (117.8 g, Kraft Canada Inc.) mixed with cheese powder (25.7 g, Kraft Canada Inc.), skim milk (82.5 g, Parmalat Canada, Etobicoke, Ont., Canada), and no-sodium margarine (5.6 g, Fleischmann's, ConAgra Foods, Omaha, Nebr., USA). Macaroni was cooked for 8 min in boiling water, drained, and then mixed with the milk, margarine, and cheese. It was prepared the morning of the session immediately before consumption. Pulses were analyzed for nutritional composition using proximate analysis, and the nutritional composition of all other ingredients was based on information provided by the manufacturers. Proximate analysis was conducted by Maxxam Analytics (Mississauga, Ont., Canada), using standard methodology (food core analysis). Maxxam Analytics is a professional analytical service accredited by the Standards Council of Canada, and is an ISO 17025-accredited food-analysis laboratory. Their food core analysis included ash (AOAC 923.03, CAM SOP-00713), calories (CAM WI-00708), carbohydrates (CAM WI-00708), total fat (AOAC gravimetric methodology), moisture (AOAC methodology, CAM SOP-00715), and protein (AOAC 992.15, CAM SOP-00711). Water was provided with the pulse (250 mL) and macaroni and cheese (450 mL) treatments. Additional water was provided with the macaroni and cheese to compensate for the difference in volume between

**Table 1.** Nutritional composition of treatments meals.

| | Macaroni and cheese | Macaroni and chickpeas | Macaroni and lentils | Macaroni and yellow peas |
|---|---|---|---|---|
| Energy (kcal) | 604.1 | 603.2 | 597.3 | 595.7 |
| Weight (g) | 446.5 | 757.7 | 756.2 | 762.1 |
| Energy density (kcal·g$^{-1}$) | 1.4 | 0.8 | 0.8 | 0.8 |
| Volume (mL) | 650.0 | 850.0 | 850.0 | 850.0 |
| Available carbohydrate (g) | 100.4 | 98.7 | 103.2 | 103.5 |
| Fiber (g) | 2.8 | 18.3 | 18.7 | 14.1 |
| Protein (g) | 22.8 | 26.1 | 29.1 | 28.3 |
| Fat (g) | 12.6 | 12.5 | 8.7 | 8.5 |

**Note:** Composition of the pulses was determined with proximate analysis (food core analysis), conducted by Maxxam Analytics (Mississauga, Ont., Canada). The composition of the nonpulse ingredients was provided by the manufacturers.



the pulses and the macaroni and cheese. Subjects were asked to consume all of the provided water.

### Protocol

As previously reported (Wong et al. 2009), subjects chose a time between 0800 and 1100 hours to participate. Subjects arrived at the study room in the Department of Nutritional Sciences at the University of Toronto following an overnight fast (10–12 h). Water was permitted up until 1 h before the start of the session.

During the sessions, BG was measured with a glucose meter (Accu-Chek Compact Plus, Roche Diagnostics, Laval, Que., Canada), and blood samples were obtained with finger prick by a Monojector Lancet Device (Sherwood Medical, St. Louis, Mo., USA), as described elsewhere (Anderson et al. 2010).

Upon arrival for the sessions, subjects completed questionnaires assessing their sleep, stress, compliance with fasting, and pattern of activity. If they reported significant deviations from their usual pattern, they were asked to reschedule. Prior to treatment consumption, subjects were administered a motivation to eat 100-mm visual analogue scale to measure subjective appetite (Flint, Raben et al. 2000), which has been used in previous studies (Akhavan and Anderson 2007; Samra and Anderson 2007; Hamedani et al. 2009; Wong et al. 2009). A baseline BG measurement was then taken. A value $\geq$6 mmol·L$^{-1}$ suggested that the subject had not fasted and the session was rescheduled. After these baseline measures, subjects consumed the treatment or control meal within 20 min. Meals were provided as a fixed amount (isocaloric), and subjects consumed the entire meal. BG and appetite were measured at 20, 40, 60, 80, 110, 140, 200, and 260 min after consumption of the treatment meal, and are reported as prepizza meal values.

FI was measured at an ad libitum pizza test meal provided 260 min after the treatment or control meal. Subjects were instructed to eat until they were “comfortably full.” Three varieties (Pepperoni, Deluxe, and Three Cheese) of Deep ’n Delicious pizza (McCain Foods, Florenceville, N.B., Canada) were offered to subjects, according to their preference at screening; their same choices were provided at all sessions. The pizzas averaged 10.0 g of protein, 7.6 g of fat, 26.6 g of carbohydrate, and 226 kcal per 100 g. Each cooked pizza (8 min at 227 °C and cut in quarters) was weighed before serving. Fresh pizzas trays replaced the previous tray at 8 min intervals until the subjects declined further trays. Each tray contained 2 pizzas of their first choice and one each of their second and third choices.

Following the pizza meal, at 280, 300, 320, and 340 min after consumption of the treatment or meal, BG and appetite were measured; they are reported as postpizza meal values.

### Statistical analysis

The average subjective appetite score was calculated from the motivation to eat visual analogue scale questionnaire, as follows: appetite score = [desire to eat + hunger + (100 – fullness) + prospective consumption]/4 (Flint et al. 2000; Woodend and Anderson 2001; Anderson and Woodend 2003; Anderson et al. 2010). Energy intake from the pizza meal was calculated from the weight consumed and the compositional information provided by the manufacturer. Cumulative and pre- and postpizza meal net incremental area under the curves (AUCs) for BG, and cumulative and pre- and postpizza meal net area above the curve (AACs) for average appetite were calculated for the 0–340-min period, 0–260-min period, and the 260–340-min period, respectively (Wolever 2006; Wolever et al. 1991).

SAS, version 9.2 (Statistical Analysis Systems, SAS Institute Inc. Carey, N.C., USA), was used for statistical analyses. All ANOVAs included session as a repeated measure to control for within-subject variability. Three-way repeated-measures ANOVAs determined the effects of treatments, time, and the time × treatment interaction on BG and average appetite scores over the time of the experiment, followed by 2-way repeated-measures ANOVAs to determine the effects of treatment at the specific time points. The effect of treatments on FI at the pizza meal and on BG AUC and average appetite AAC were determined with a 2-way repeated-measures ANOVAs. Tukey–Kramer post hoc test was used to describe mean differences among treatments. All results are presented as means ± standard error (SE). The statistical significance was achieved when the $p$ value was less than 0.05.

## Results

### Subject characteristics

Subjects had a mean age of 21.3 ± 0.5 years, a mean weight of 67.7 ± 1.2 kg, and a mean BMI of 21.6 ± 0.3 kg·m$^{-2}$.

**Table 2.** Pizza meal and cumulative food intake.

| | Pizza meal | | | Cumulative | | |
|---|---|---|---|---|---|---|
| Treatment | Energy (kcal) | Weight (g) | Volume (mL) | Energy (kcal) | Weight (g) | Volume (mL) |
| Macaroni and cheese | 1435.7±62.8a | 637.9±27.4a | 703.2±30.1a | 2039.8±62.8a | 1084.4±27.4a | 1353.2±30.1a |
| Chickpea | 1405.2±67.2ab | 623.7±30.3ab | 688.2±33.0ab | 2008.4±67.2ab | 1381.4±30.3b | 1538.2±33.0b |
| Lentil | 1365.7±70.0b | 606.7±31.4b | 669.1±34.2b | 1963.0±70.0b | 1362.9±31.4b | 1519.1±34.2b |
| Yellow pea | 1334.9±69.2b | 593.0±31.4b | 653.4±33.7b | 1930.6±69.2b | 1355.1±31.8b | 1503.4±33.7b |
| *p* | 0.0100 | 0.0040 | 0.0050 | 0.0060 | <0.0001 | <0.0001 |

**Note:** All values are means ± SE ($n = 25$). Two-way ANOVA, followed by Tukey–Kramer post hoc test. Values in the same column with different letters are significantly different from each other ($p < 0.05$). Pizza meal values were measured at an ad libitum pizza meal 260 min following the consumption of the treatment meals. The cumulative values equal the amount consumed at the treatment meal plus the pizza meal.



### Food and water intake

The lentil and yellow pea treatments led to lower energy ($p = 0.01$), weight ($p = 0.004$), and volume ($p = 0.005$) intake, compared with the macaroni and cheese treatment (Ta-Table 2). As expected, there was an effect of treatment on cumulative FI (treatment meal plus pizza meal) (Table 2). The lentil and yellow pea treatments led to lower cumulative energy intake ($p = 0.006$); however, all the pulse treatments led to lower weight and volume intakes, compared with the macaroni and cheese treatment ($p < 0.05$). There was no effect of treatments on water intake ($p = 0.31$, data not shown).

### Average appetite

There was an effect of time ($p < 0.0001$) and treatment ($p = 0.0003$), but no time × treatment interaction ($p = 0.23$) for prepizza meal average appetite (Fig. 1). Regardless of treatment, appetite was highest when subjects first arrived (71.9 ± 1.4 mm), but immediately decreased at 20 min upon completion of the treatment meal (15.6 ± 1.0 mm), and gradually returned to baseline levels by 260 min (70.1 ± 1.8 mm). In support of the effects of treatment on FI, the lentil (41.8 ± 1.8 mm) and yellow pea (42.9 ±1.7 mm) treatments led to lower average appetite scores (indicating greater satiety) during the prepizza meal 260 min period, compared with the macaroni and cheese treatment (49.7 ± 1.7 mm), whereas the chickpea treatment led to intermediate scores (46.2 ± 1.7 mm; $p < 0.05$). The overall effect of lentils on suppression of appetite, compared with macaroni and cheese, is seen at multiple time points during the prepizza meal period, including at 60, 80, 110, 140, and 200 min (Fig. 1). In addition, the yellow pea treatment suppressed appetite at 200 min, compared with the macaroni and cheese treatment (Fig. 1).

Although there was an effect of time ($p < 0.0001$) on postpizza meal average appetite, there was no effect of treatment ($p = 0.93$), and there was no time × treatment interaction ($p = 0.10$). Immediately after the pizza meal, appetite sharply decreased to 12.8 ± 1.1 mm, and gradually increased over the next hour to 28.3 ± 1.3 mm. Average appetite scores over the 1-h postpizza meal period were as follows: 30.6 ± 2.3, 29.9 ± 2.2, 31.4 ± 2.2, and 30.6 ± 2.2 mm for the macaroni and cheese, chickpea, lentil, and yellow pea treatments, respectively.

Although the lentil and yellow pea treatments reduced prepizza meal average appetite, there was no effect of any of the treatments on cumulative ($p = 0.18$), prepizza meal ($p = 0.07$), or postpizza meal AAC ($p = 0.18$) (Table 3).

### Blood glucose

There was no effect of treatment on prepizza meal BG ($p = 0.24$); however, there was an effect of time ($p < 0.0001$) and a time × treatment interaction ($p = 0.0008$), which was explained by variation in the response to treatments over time (Fig. 2). The BG response following the pulse treatments increased at a slower rate than following the macaroni and cheese treatment to 20 min ($p < 0.05$) (Fig. 2). In addition, the macaroni and cheese treatment resulted in a second peak in BG at 140 min, whereas the pulse treatments did not. At 140 min, BG was higher in response to the macaroni and cheese treatment than to the lentil treatment; the other pulse treatments led to intermediate BG concentrations ($p < 0.05$) (Fig. 2).

There was an effect of treatment ($p = 0.02$) and time ($p < 0.0001$) on postpizza meal BG, and a time × treatment interaction ($p = 0.002$) (Fig. 2). Immediately following the pizza meal, BG was lower following the chickpea and lentil treatments than for the macaroni and cheese treatment ($p < 0.05$), but there were no differences among the treatments at the remaining times (Fig. 2).

The effect of treatment on prepizza meal BG AUC approached significance ($p = 0.07$), whereas postpizza meal BG AUC was highest after the yellow pea treatment, and was significantly higher than after the lentil and chickpea treatments ($p = 0.002$) (Table 4). Cumulative BG AUC (0–340 min) was affected by treatment ($p = 0.02$), and was lower following the chickpea treatment, compared with the macaroni and cheese treatment (Table 4).

### Palatability of treatments and pizza meal

There were no differences in the ratings of treatment palatability ($p = 0.67$). Macaroni and cheese, chickpea, lentil, and yellow pea treatment ratings were 65.3 ± 4.6, 60.7 ± 5.3, 61.6 ± 4.3, and 64.0 ± 4.3, respectively. There was also no effect of treatment on the ratings of pizza palatability at the ad libitum meal over the 4 sessions ($p = 0.43$). Pizza palatability ratings following the macaroni and cheese, chickpea, lentil, and yellow pea treatments were 80.3 ± 3.1, 80.8 ± 3.0, 78.8 ± 3.1, and 78.1 ± 2.9, respectively.

## Discussion

When pulses were incorporated into a meal with a high-glycemic carbohydrate food, their effect on appetite, FI at a later meal, and BG response to that next meal were dependent on the type of pulse consumed. The lentil and yellow pea treatments, but not the chickpea treatment, suppressed pre-

**Fig. 1.** The effect of pulse meals on appetite ratings. Treatments were macaroni and cheese, chickpea, lentil, and yellow pea. Three-way ANOVA, time (prepizza meal, $p < 0.0001$; postpizza meal, p < 0.0001), treatment (prepizza meal, $p = 0.0003$; postpizza meal, $p = 0.93$), and time × treatment interaction (prepizza meal, $p = 0.23$; postpizza meal, $p = 0.10$), followed by a 2-way ANOVA and Tukey–Kramer post hoc test, identified differences among treatments ($p < 0.05$). Values with different letters are significantly different at each time point ($n = 25$).

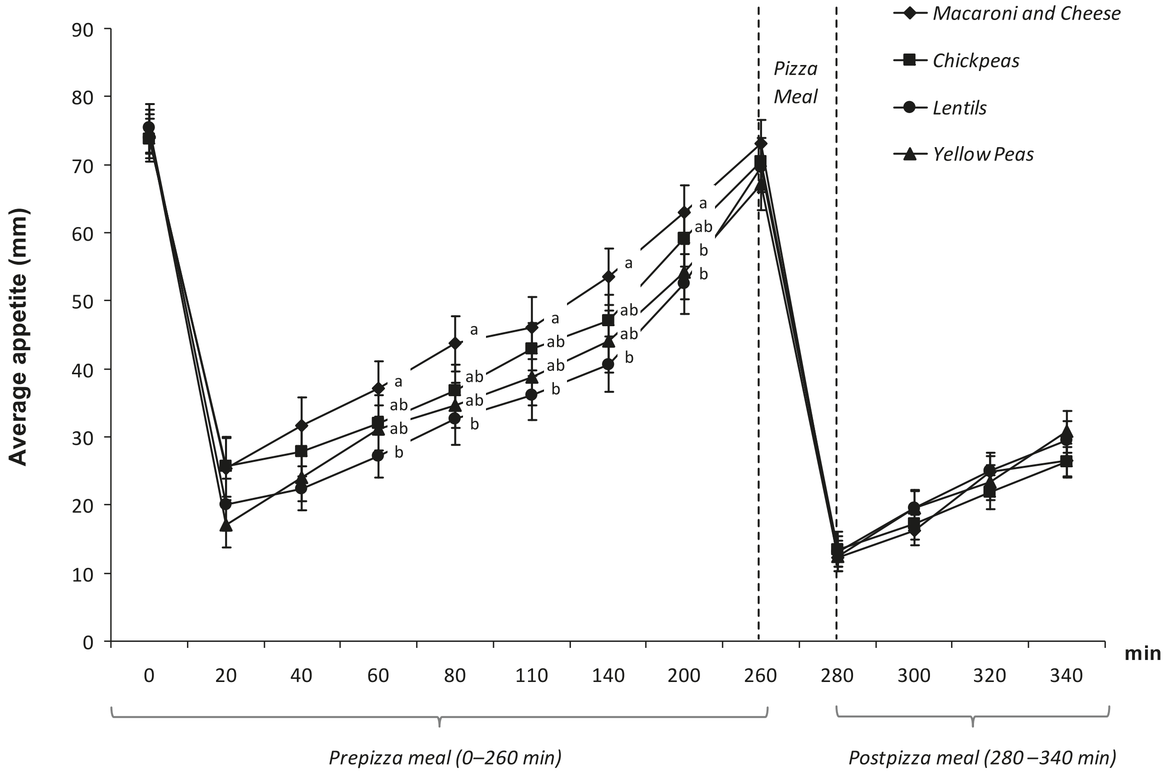


**Table 3.** Pre- and postpizza average appetite area above the curve (AAC).

| | Average appetite AAC (mm·min) | | |
|---|---|---|---|
| Treatment | Cumulative | Prepizza meal | Postpizza meal |
| Macaroni and cheese | –9 616.7±1 353.5 | –5764.8±1095.5 | –3782.3±317.3 |
| Chickpea | –10 581.3±1 173.2 | –6754.2±963.8 | –3512.9±217.7 |
| Lentil | –12 354.7±1 293.1 | –8472.1±1015.1 | –3421.0±283.7 |
| Yellow pea | –11 861.0±1 335.7 | –7999.1±1077.5 | –3283.4±285.0 |
| *p* | 0.18 | 0.07 | 0.18 |

**Note:** All values are means ± SE ($n = 25$). Two-way ANOVA. Cumulative period, 0–340 min; prepizza meal period, 0–260 min; postpizza meal period, 260–340 min.

pizza meal appetite and FI at the later meal, compared with the macaroni and cheese treatment. The lentil and chickpea treatments, but not the yellow pea treatment, resulted in lower postpizza meal BG.

To our knowledge, this is the first report of the effects of different types of pulses consumed in a meal on first and second meal BG and appetite responses and on FI at a subsequent meal. Pulses were added to a meal with another carbohydrate source because they are usually consumed with high-GI foods, such as rice, pasta, and bread. In this study, pulses were consumed with macaroni, and accounted for 42% of the calories (250 kcal) in the meal and an average of 40 g of available carbohydrate. This amount is approximately 2 servings (1.5 to 2.0 cups), based on Canada's Food Guide, and matched the quantity provided in previous studies investigating the effects of pulses consumed alone on BG, appetite, and FI control (Wong et al. 2009). A treatment meal of 600 kcals was provided to represent an average breakfast or lunch meal. For example, Canadian men consume, on average, 2660 kcal per day, with approximately 17% of calories (452 kcal) eaten at breakfast and 23% (612 kcal) eaten at lunch (Garriguet 2007). In addition, the treatment meals were a fixed amount (isocaloric), to allow for comparison among the pulse and macaroni and cheese treatments without the variability of different FI. The amount of time between treatment consumption and the subsequent ad libitum test (pizza) meal was based on previous studies that investigated the second meal effects of foods or food components on BG (Jenkins et al. 1982; Liljeberg et al. 1999; Nilsson et al. 2008).

Although pulses lowered the BG response immediately following their consumption at 20 min and lentils lowered the BG at 140 min, they did not affect prepizza meal BG AUC over 140 min ($p = 0.30$, data not shown) or 260 min ($p =$

**Fig. 2.** The effect of pulse meals on blood glucose concentrations. Treatments were macaroni and cheese, chickpea, lentil, and yellow pea. Three-way ANOVA, time (prepizza meal, $p < 0.0001$; postpizza meal, $p < 0.0001$), treatment (prepizza meal, $p = 0.24$; postpizza meal, $p = 0.02$), and time × treatment interaction (prepizza meal, $p = 0.0008$; postpizza meal, $p = 0.002$), followed by a 2-way ANOVA and Tukey–Kramer post hoc test, identified differences among treatments ($p < 0.05$). Values with different letters are significantly different at each time point ($n = 25$).

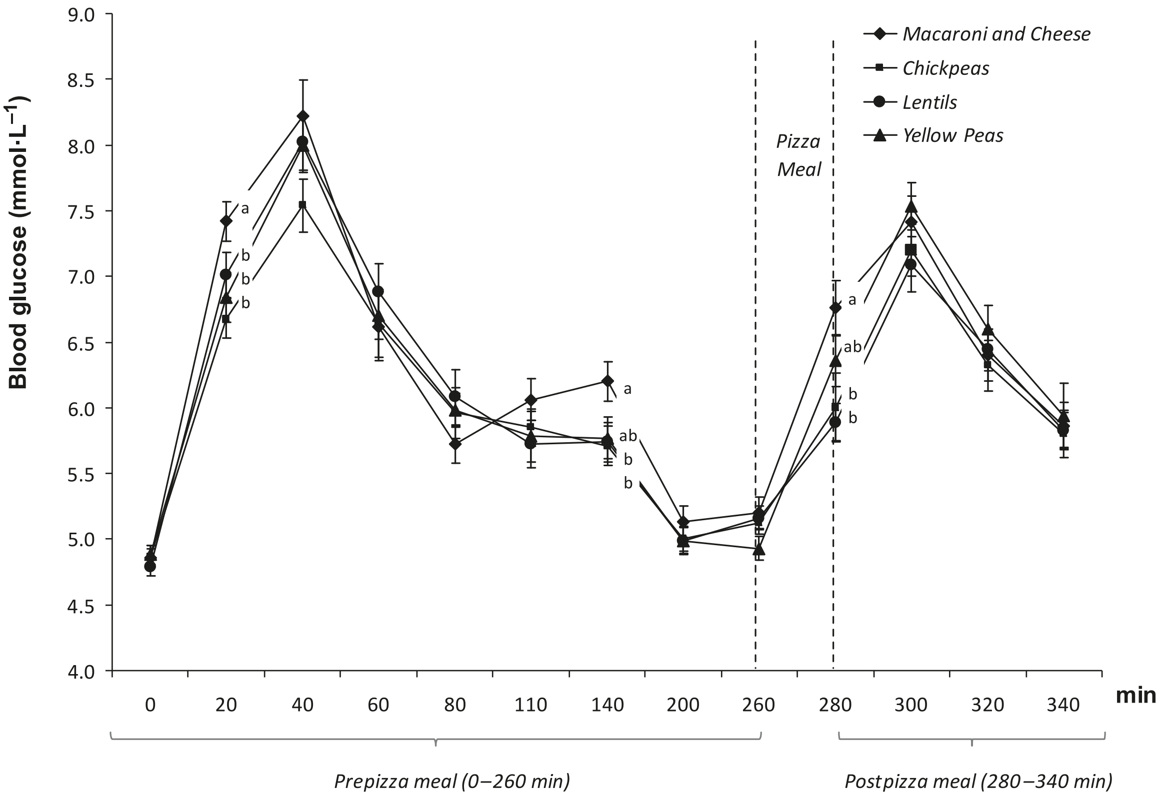


**Table 4.** Pre- and postpizza meal blood glucose (BG) area under the curve (AUC).

| | BG AUC (mmol·min·L$^{-1}$) | | |
|---|---|---|---|
| Treatment | Cumulative | Prepizza meal | Postpizza meal |
| Macaroni and cheese | 431.3±25.3a | 298.1±17.8 | 105.6±15.3ab |
| Chickpea | 344.5±32.0b | 232.0±22.7 | 90.0±10.8b |
| Lentil | 392.9±32.7ab | 276.8±28.3 | 85.6±10.6b |
| Yellow pea | 367.3±30.5ab | 239.5±22.5 | 125.9±11.2a |
| *p* | 0.020 | 0.070 | 0.002 |

**Note:** All values are means ± SE ($n = 25$). Two-way ANOVA, followed by Tukey–Kramer post hoc test. Values in the same column with different letters are significantly different from each other ($p < 0.05$). Cumulative period, 0–340 min; prepizza meal period, 0–260 min; postpizza meal period, 260–340 min.

0.07). In previous studies of pulses consumed alone, compared with white bread, the reduction in BG was sustained for 2 h. Specifically, white bread led to 57%, 82%, and 31% higher prepizza meal BG AUC, compared with chickpeas, lentils, and yellow peas, respectively (Wong et al. 2009). Pulses have a reported GI averaging between 30 and 45 (depending on the pulse type and study), whereas macaroni and cheese has a reported GI of 92 (GI based on white bread) (Foster-Powell et al. 2002). Thus, it was expected that a pulse meal with macaroni would lead to a lower prepizza meal BG response than macaroni and cheese. Despite not reaching significance, the pulse treatments resulted in a lower prepizza meal BG AUC response over 260 min than the macaroni and cheese treatment (28%, 8%, and 25%, for the chickpea, lentil, and yellow pea treatments, respectively). Based on the assumption that the majority of the GI of macaroni and cheese is from the macaroni, we estimate that the glycemic load of our treatments (60.0, 62.5, and 64.3 for the chickpea, lentil, and yellow pea treatments, respectively) were roughly 33% lower than that of macaroni and cheese (92.9). Thus, a lower prepizza meal BG AUC of 25%–28% in response to the pulse treatments, compared with the macaroni and cheese treatment, is reasonable. However, it was unexpected that the lentil treatment would only lead to an 8% lower prepizza meal BG AUC, because it has a reported GI of 41 and it was the most effective pulse when consumed alone, compared with white bread (Wong et al. 2009).

Prepizza meal BG results from this study indicate that a time period of longer than 2 h may be required to fully describe the glycemic response to certain foods and (or) meals. At 140 min, there was a second BG peak in response to the macaroni and cheese treatment, which was higher than that in response to the lentil treatment. This second peak is important because it occurred 2 h and 20 min after the consumption of macaroni and cheese began. Traditionally, the GI of foods is calculated only over 2 h from the start of consumption; consequently, this second peak would not be incorporated in the calculation. It has been stated that it is probable that there could be effects on the GI beyond 2 h, and they can vary for different types of foods (Brouns et al. 2005).

Findings from our study, as well as those from a previous study (Wong et al. 2009), suggest that FI at a later meal cannot be predicted from the GI of foods. The pulse treatments led to lower BG immediately following consumption at 20 min; however, they did not significantly lower the prepizza meal BG AUC response over 260 min ($p = 0.07$), compared with the macaroni and cheese treatment. Despite this, the lentil (8% lower prepizza meal BG AUC) and yellow pea (25% lower prepizza meal BG AUC) treatments led to lower FI at the pizza meal than the macaroni and cheese treatment. As well, although there was no effect on prepizza meal appetite AUC ($p = 0.07$), the lentil and yellow pea treatments led to significantly lower average appetite ratings over the 260-min prepizza meal period. In addition, the chickpea treatment did not significantly lower FI or appetite, compared with the macaroni and cheese treatment, even though it resulted in the lowest prepizza meal BG AUC (28% lower). To further support our findings, at 260 min (immediately before the pizza meal), BG was correlated positively with FI ($r = 0.21$, $p = 0.03$), which is in contrast to the suggestion that high-GI foods lead to hypoglycemia rebound, resulting in higher FI (Roberts 2000).

The second meal effect we observed on BG cannot be explained by the FI at the pizza meal. As expected, ad libitum FI was affected by treatment, but the treatment effects on postpizza meal BG and FI were independent. Subjects consumed the least amount of calories in response to the lentil and yellow pea treatments, yet the yellow pea treatment resulted in the highest postpizza meal BG AUC. In contrast, the chickpea treatment did not reduce FI at the later meal, but reduced postpizza meal BG. Thus, it is clear that the effects on postpizza meal BG go beyond caloric intake, and may be attributed to differences in their composition. To further understand the second meal effects of pulses on BG, measurements after a meal of fixed calories and carbohydrate content for a longer period of time (a minimum of 2 h) are required to remove the effect of the interaction of prepizza meal treatments with FI at the pizza meal on BG.

The second meal effect of the pulse treatments cannot be explained by their effect on BG prior to the pizza meal. It has been proposed that the lower BG following a second meal is in response to a low but sustained net incremental increase in BG following the consumption of low-GI foods (Jenkins et al. 1982; Liljeberg et al. 1999; Nilsson et al. 2008). In our study, the pulse treatments did not significantly lower prepizza meal BG AUC (with the lentil treatment having the smallest effect of 8%), yet the lentil and chickpea treatments lowered BG at 280 min, compared with the macaroni and cheese treatment. In addition, even though the yellow pea treatment led to a lower BG response following consumption at 20 min and a 25% lower BG AUC than the macaroni and cheese treatment, it led to the highest postpizza meal BG AUC. Therefore, as has been shown previously, factors independent of GI (Brighenti et al. 2006; Hlebowicz et al. 2007) contribute to the second meal effect of foods.

Differences in energy density, weight, and volume could have contributed to the effects of the lentil and yellow pea treatments on prepizza meal average appetite and FI at the pizza meal. Both energy density and amount of food consumed affect subsequent appetite and energy intake (Wolever et al. 1988; Moghaddam and Wolever 2005). Although the pulse and macaroni and cheese treatments provided a comparable number of calories, the pulse treatments weighed more, had greater volume, and had lower energy densities (0.8 $kcal{\cdot}g^{-1}$), than the macaroni and cheese treatment (1.4 $kcal{\cdot}g^{-1}$). However, despite all the pulse treatments having the same energy density, the chickpea treatment did not lower prepizza meal appetite or FI at the pizza meal.

Macronutrient composition of the pulse treatments could have also contributed to differences in appetite and FI at the pizza meal. The lentil and yellow pea treatments were higher in available carbohydrate and protein and lower in fat than the chickpea and macaroni and cheese treatments (Table 1). Protein is more satiating than carbohydrate, and both are more satiating than fat (Anderson et al. 2004, 2006). However, regardless of small differences in macronutrients between the pulse treatments, it was surprising that chickpeas did not suppress appetite or FI.

Differences in the liking of the pulse treatments and macaroni and cheese do not explain differences in appetite or FI. The pulse and macaroni and cheese treatments were different in flavor and texture. However, these factors did not appear to influence the enjoyment of the pulse or macaroni and cheese treatments, as indicated by the fact that there was no difference in palatability ratings. Nevertheless, it is possible that variations in flavor and texture affected appetite and FI at the pizza meal in a way that was not quantified by the palatability visual analogue scale questionnaire. It is important to note that the pulse and macaroni and cheese treatments are not typical breakfast meals. But, because this issue is the same for all the meals and because their palatability ratings were not different, this did not contribute to the effects on appetite or FI 4 h later.

The enjoyment of the pizza meal 4 h after consumption of the pulse and macaroni and cheese treatments does not explain differences in FI. As expected, palatability ratings of the pizza indicated that the participants enjoyed the ad libitum meal. However, because the pulse and macaroni and cheese treatments were all followed by the same pizza meal 4 h later and subjects were asked to eat until comfortably full, how much they enjoyed the pizza did not contribute to the effects on FI. This is also supported by the fact that there were no differences in the palatability ratings of the pizza across the sessions, and that the amount eaten at the meal was similar to that reported in previous studies investigating the effects of foods and food components on FI (Akhavan and Anderson 2007; Samra and Anderson 2007; Wong et al. 2009; Anderson et al. 2010).

Many composition aspects differ between the pulse and the macaroni and cheese treatments. The pulse treatments provided 11–16 g more dietary fiber, but this does not explain the effects of pulses on appetite, FI, or postpizza meal BG. Because of a lack of detailed information about the composition of pulses, the components responsible for these effects and why they vary among the types are unknown. It is possible that processing, food matrix, or the composition of starch or fiber differ among the pulses, which would affect digestibility and physiological action.

These data support recommendations for the regular inclusion of pulses in the diet to improve glycemic, appetite, and FI control. It is important to note that this study was conducted in young normal-weight males, so further research into the effects of pulses on BG, appetite, and FI regulation in other populations, including females, overweight or obese adults, and children, is required. In addition, Canada is the second largest producer of pulses in the world, and the pulse industry in Canada is valued at more than $1 billion per year (Hoover et al. 2010); however, the majority of pulses produced in Canada are exported (Agriculture and Agri-Food Canada 2010). Therefore, not only would the regular consumption of pulses improve the health of Canadians, it would also support the Canadian economy.

In conclusion, the beneficial effects of consuming a pulse meal on appetite, FI at a later meal, and the BG response to a later meal are dependent on pulse type. These differences between pulse types are most likely explained by variations in composition. Further research exploring the different components of pulses and their impact on appetite, FI, and second meal BG control is necessary to understand their associations with lower body weight and risk of obesity and to provide insight as to why the different pulse types have different effects.

## Acknowledgements

This study was funded by Pulse Canada under the Pulse Innovation Project. We would also like to acknowledge the assistance of Dr. France Cho, Yudan Liu, Nandini Mehta, Shokoufeh Khodabanden, Angelica Zykus, and Chris Smith. None of the authors have any conflicts of interest. Rebecca Mollard was involved in the design of the study, treatments, and coordination of the study, and was responsible for data analysis and writing of the manuscript. Christina Wong was responsible for treatment development, subject recruitment, running sessions, data collection, coordination of the study, managing research assistants, and reviewing of the manuscript. Bohdan Luhovyy was responsible for managing students and research assistants, communication with the funding agency, and reviewing the manuscript. G. Harvey Anderson was the principal investigator, responsible for conceptualization and design of the study, coordination of the research team, and reviewing of the manuscript.

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