Almond paste and dietary fiber: A novel way to improve postprandial glucose and lipid profiles?

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Asia has become the epicentre of type 2 diabetes (T2D), predominately due to the consumption of carbohydrate-rich and high-glycemic-index diets. Previously, almond consumption has been reported to reduce the risk of T2D, obesity, and related diseases. The hypothesis of this randomised cross-over clinical trial was that almond paste consumption with bread would improve postprandial glycemic and insulinemic responses. Fifteen healthy Chinese men consumed four bread-based meals containing 50 g of available carbohydrate and different amounts of almond paste and inulin. Co-ingesting bread with 15 g of almond paste and 4 g of inulin significantly reduced the postprandial glucose and insulin levels. However, co-ingestion of almond paste with bread increased the triglyceride levels. We conclude that co-ingestion of almond paste and/or inulin with bread had beneficial effects on human health, but further studies will be required to demonstrate these effects on a long term basis.

Keywords: Almond paste; dietary fiber; inulin; blood glucose; lipid profiles

Introduction

It has long been recognized that the consumption of almonds can benefit human health as they are rich in protein (~25% of energy), fibers, vitamins, and minerals, and contain healthy monounsaturated (MUFA) and polyunsaturated (PUFA) fatty acids (Ros 2010). The contribution that almonds make human health has been extensively studied. It was well established that regular almond consumption had beneficial effects on glycemic control, insulin resistance, lipid metabolism, and lipid peroxidation (Tan and Mattes 2013; Berryman et al. 2015). Despite its high energy density, the consumption of almonds did not promote weight gain in healthy subjects (Berryman et al. 2015; Hollis and Mattes 2007). Moreover, almond consumption during energy restriction decreased truncal fat and blood pressure in obese subjects (Dhillon et al. 2016).

The lipid fraction in almonds was believed to play a beneficial effect on human health. Previous studies demonstrated that daily consumption of 10-100 g of almonds was associated with improvement in lipid metabolism and glucose homeostasis. In addition, the high fiber content in almonds might be the major factor related to the increased satiety and weight control. Almond consumption (43 g/d) at snack time reduced postprandial blood glucose and increased satiety over a four-week period (Tan and Mattes 2013). Similarly, the consumption of 60 g/d of almonds for four weeks reduced serum insulin levels and insulin resistance (Li et al. 2011). Moreover, the plasma α-tocopherol level increased but the total cholesterol (TC) and low-density lipoprotein (LDL-c) levels decreased. The changes in lipid profile were probably due to the fatty acid composition of almonds. Previously, different components of almonds were reported to contribute to various health benefits. For example, the glycemic-lowering effect of almonds was due to the high contents of fats and proteins, which decreased the gastric emptying rate and stimulated insulin secretion. Moreover, the dietary fibers in almonds increased the viscosity of the intestinal contents and retarded carbohydrate absorption (Ou et al. 2001). The phenolic compounds in almond skins inhibited the amylase activity and thus hindered the carbohydrate absorption (Tsujita et al. 2013; Jenkins et al. 2006).

According to Gebauer et al. (2016), the metabolizable energy of almonds was dependent on the form in which they were consumed. Consumption of almond oil with defatted almond flour significantly decreased 3-h blood glucose incremental area under the curve, but no difference in insulin response compared to small almond particles (Berry et al. 2008). Similarly, Burton-Freeman et al. (2004) reported higher cholecystokinin (CCK) concentrations and greater satiety after consumption of almond oil compared to whole almonds. These results, when combined, suggested that the

bioavailability of the lipid fraction in almonds might be responsible for the decreased postprandial glycemia. In contrast to consuming intact almonds, almond paste is an economically valuable product produced from almonds. Like peanut butter that is extensively consumed with bread as sandwiches, almond paste is increasingly become a popular spread. Almond paste is widely used in fillings, cakes, cookies, breads, and tarts. Similar to almonds, almond paste may decrease postprandial glycemia and insulinemia. However, its effects on postprandial glucose and insulin responses have not been studies systematically. Therefore, the first aim of this study was to determine the dose-response effects of almond paste, which was ground and refined from almond without skin, on the postprandial glucose, insulin, and cholesterol in healthy subjects. Bread was chosen as the test model as it is a high glycemic index, but a popular staple all over the world.

Additionally, dietary fiber has been reported to improve risk factors for the chronic diseases and have beneficial effects on blood glucose concentrations (Silva et al. 2013). Long-term consumption of up to 15 g/d of fibers was associated with significant reduction in fasting blood glucose (Silva et al. 2013). The reduction was attributed to the high viscosity imparted to foods by adding viscous fibers, which lead to a delayed gastric emptying and delayed absorption (Jenkins et al. 1978). For non-viscous fibers, the reduction was due to the fiber enclosing the endosperm (Jarvi et al. 1995). Despite the positive effects of dietary fibers on glycemia, inconsistent results have been obtained (Post et al. 2012). Inulin is a starchy substance exist naturally in various fruits, vegetables, and herbs. Inulin is being added to a lot of food products, but limited studies have been conducted on the glycemic effects of co-ingesting inulin and almond paste. Therefore, the second aim of the present study was to examine the effects of adding inulin in almond paste on blood glucose response of the white bread. Given

the availability of almond paste and dietary fiber on the market, the enrichment of a white bread, which is carbohydrate-rich, with an amount of almond paste and fiber provides the bread option with desirable properties.

Methods

Participants

The inclusion criteria were healthy Chinese male participants living in Singapore with a body mass index (BMI) between 18-25 kg/m^2, aged 21-60 years and fasting blood glucose (FBG) < 6 mmol/L. Participants on special or weight loss diet, taking drugs known to affect glucose metabolism, body fat distribution, appetite, food intake or energy metabolism were excluded from the study. Study protocol was explained in detail and participants gave their informed consent before participation. The study was conducted in accordance with the guidelines laid down in the Declaration of Helsinki, and all procedures involving human participants were approved by Domain Specific Review Board (DSRB) of National Healthcare Group, Singapore (Reference number 2019/00701). All hard copies of the data collected will be filed and stored in secure key-access cabinets located at the Clinical Nutrition Research Centre (CNRC). The researchers are the only authorized staff with access-the locked cabinets. Additionally, working data files containing non-identifiable information only will be stored on the computers, which are password protected. Access to the files will be restricted to the research team members.

Study protocol

Upon determination of the participants' eligibility, they underwent 4 separate treatments separated by a minimum of 5-day washout between visits as shown in the Table 1. A standard dinner consisting of CP teriyaki chicken with rice (CPF Thailand Public Co.

Ltd., Thailand) and a packet of Carman's Nut Bar (Almond with Hazelnut and Vanilla, Australia) was provided before each session. All participants were asked to refrain from consuming any other foods except plain water and fast for 10-12 h.

Participants arrived at the laboratory around 8:30 am following the overnight fast. Body fat percentage was measured using the bioelectrical impedance analysis (BIA) device (Tanita BC-418, Tokyo, Japan) and dual-energy x-ray absorptiometry (DEXA, QDR 4500 A, fan-beam densitometer, Hologic, Waltham, USA, software version 8.21). Fasting blood glucose (FBG) was measured via finger prick to confirm overnight fasting. Thereafter, a blood catheter was inserted in the antecubital vein of the upper arm, which was kept patent by flushing with 3 mL of non-heparinised saline. Participants were required to rest for 15 min, before 6 mL of baseline blood sample (0 min) was taken. Immediately after that, participants were served a test meal, where they were required to consume within 12 min. Fifteen minutes later, 6 mL of blood samples were collected into an EDTA-vacutainer at 15-min intervals for an hour, i.e. 15, 30, 45, and 60 min. For the next two hours, the blood samples were collected at 90, 120, 150, and 180 min. Blood samples were centrifuged at 1500 rpm for 10 min at 4 °C and the supernatant plasma was aliquoted and stored at -80 °C until analysis. Plasma samples were sent to National Referral Laboratories (NRL) Pte Ltd, Singapore to measure the glucose, insulin, cholesterol, and triglyceride concentrations.

Meals

Four different meals, including a control meal (white bread, B) and 3 test meals, were consumed in random order, each containing 50 g of available carbohydrate (Table 2). Almond paste and inulin were provided by Glico Asia Pacific Pte Ltd.

Statistical analysis

Statistical analysis was performed using Statistical Product and Service Solutions (SPSS) software version 23 (IBM, Armonk, NY, USA). All data were expressed as means ± SD (standard deviation). For each subject, the incremental area under the curve (iAUC) for postprandial glucose and insulin response was calculated for both the test and control treatment using the trapezoidal rule (FAO/WHO, 1998). Fasting and AUC concentrations of glucose and insulin was compared between trials using a one-way repeated measures ANOVA. Postprandial glucose and insulin responses across time were compared using a two-way ANOVA. Two-sided $p < 0.05$ was considered statistically significant in all cases.

Results

Table 3 shows the baseline characteristics of the studied population. The average age of the participants was 37.8 y (range, 21.5 – 55.3 y) and the average BMI was 21.5 kg/m^2 (range, 18.8 – 24.6 kg/m^2). The average FBG was found to be 5.2 mmol/L (range, 4.6 – 5.8 mmol/L).

Figure 1a shows the mean blood glucose over 3 h testing period for the different test meals with different temporal profiles. All of the 3 test meals and the control white bread meal reached peaks at 45 min after the consumption. The incremental blood glucose concentrations were found to be 2.22, 1.74, 1.48, and 2.03 mmol/L for B, BA, BAF1, and BAF2, respectively. When expressed as iAUC, BAF1 showed a statistically significant reduction in glucose response over 120 min compared with B (96.5 vs 132.9 mmol·min/L, $p < 0.05$). Similarly, BA and BAF2 also showed reductions in glucose response over 120 min compared with B, but did not reach statistical significance (Fig. 1b).

Figure 2a shows that the consumption of control white bread meal and 3 test meals induced an insulin response that reached a peak at 45 min. The incremental peaks for insulin response for B, BA, BAF1, and BAF2 were found to be 42.75, 46.30, 35.22, and 45.94 mU/L, respectively. Expressed as iAUC, Figure 2b shows that co-ingestion of almond paste and/or inulin with bread induced lower insulin responses than the control white bread meal.

As shown in Figure 3a, serum TC concentrations for each meal did not differ over the 3-h testing period. Similarly, the HDL-c and LDL-c concentrations for each meal did not differ over the testing period (data not shown). However, the changes in the TG concentrations in response to the 3 test meals were greater than that following the control bread meal (Fig. 3b). Moreover, the changes in the TG concentrations in response to BA and BAF1 were greater than that following BAF2. These results, when combined, suggested that consuming almond paste with bread increased the TG levels.

Discussion

Our results clearly indicate that the addition of almond paste and inulin to white bread resulted in an improvement in the postprandial glucose and insulin response of the composite meal, which was dose-dependent. The benefits of intact almond on blood glucose and lipid metabolism have been reported previously (Tan and Mattes 2013; Li et al. 2011; Gannon et al. 1988). Due to the presence of the nutritional composition, such as high amount of protein, fat, and dietary fiber, serum insulin concentrations (Li et la. 2011), acute postprandial glycemia and acute satiety (Gannon et al. 1988) were significantly lower after intake of almond than a control meal. To the best of our knowledge, this is the first study to show that when almond paste was consumed with white bread, a lowering of the blood glucose response was observed in healthy

individuals. Moreover, co-ingesting almond paste and inulin with bread did not increase insulin response.

Previous studies have shown that proteins reduce glycemic response (Gannon et al. 2002; Nuttall et al. 1984, 2004; Quek et al. 2016). The protein content in almonds ranges from 16.82% to 23.95% (House et al. 2019), which results in a considerable amount of protein in almond paste. Hence, the lower glycemic response produced from consuming BA, BAF1 and BAF2 might be due to the protein present in almond paste. Individual amino acids are also known to reduce the glucose plasma response. It was observed that the consumption of proline and glucose reduced glucose response by more than 23% compared to the consumption of glucose alone (Nuttall et al. 2004). Consumption of glycine and glucose also induced lower glucose response (Gannon et al. 2002). Glycine and proline are present in almond protein and these two amino acids might have contributed to the lower glucose response after consumption of bread and almond paste. However, Nuttall et al (1984) reported that consumption of protein and glucose increased insulin levels compared to consumption of glucose alone. Consumption of individual amino acids and glucose does not seem to have an effect on insulin concentrations either (Gannon et al. 2002; Nuttall et al. 2004). Hence, the decrease in insulin levels for BA, BAF1 and BAF2 treatments might be due to other components in almond paste other than protein.

Besides protein, consumption of fat also reduces glycemic response (Moghaddam et al. 2006). It was observed that the glycemic response of subjects was reduced significantly after consuming glucose together with 30 g of fat. The glycemic response can be reduced by the consumption of fat through two ways (Collier and O'Dea 1983; Normand et al. 2001). Firstly, the ingestion of fat causes a delay in gastric emptying, which slows down the absorption of glucose in the small intestine. Secondly,

the ingestion of fat can cause an increase in glucose uptake by the liver and tissues such as adipose and muscle. Therefore, in our study, the lower glycemic response observed after consumption of BAF1 could also be attributed to the fat present in almonds. Monounsaturated fat is the main component of fat in almonds. It was reported that consumption of a high monounsaturated fat diet decreased the fasting blood glucose by 0.23 mmol/L in patients with diabetes. Hence, the monounsaturated fat present in the almond paste might have also contributed to the lower glycemic response (Garg 1998). Monounsaturated fat also have an effect on insulin concentrations too. Several studies have reported that consumption of a high monounsaturated fat diet reduced the insulin concentration of subjects (Garg 1998). Hence, the lower insulin levels for BA, BAF1, and BAF2 treatments could be attributed to monounsaturated fat present in almond paste.

In our study, BAF1 contained 4 g more fiber compared to BA and 5.6 g more fiber compared to B. Consumption of dietary fiber is known to reduce blood glucose. Ou et al (2001) investigated the roles of dietary fibers in vitro and proposed three mechanisms in which dietary fibers decreased blood glucose. Firstly, dietary fibers increase the viscosity of small intestinal juice and this reduces the adsorption of glucose through the small intestine. Secondly, dietary fiber will bind to free available glucose in the small intestine and thus, reducing its adsorption through the intestine. Thirdly, dietary fiber encapsulates amylase and starch and this will prevent amylase and starch from interacting with each other. Hence, this will reduce the formation of glucose. The high amount of fiber in BAF1 might be one of the factors that contributed to a significantly lower glucose response compared to B. The fiber present in almond paste might have also contributed to the decrease in insulin response. It was reported that the consumption of a high fiber diet reduced the insulin concentration in subjects by 50%

compared to the consumption of a low fiber diet (Albrink et al. 1979). Hence, the fiber present in almond fiber might have also contributed to the lower insulin response in BA, BAF1, and BAF2.

In the present study, it was observed that the changes in the TG concentrations in response to BA, BAF1, and BAF2 were greater than the changes in the TG concentrations in response to B. Within the three treatments, higher TG concentrations were observed in BA and BAF1 compared to BAF2. BA and BAF1 have higher protein, fat and fiber content compared to BAF2 and B. Hence, the increase in TG levels might be due to the presence of protein and fat. Gannon et al (1993) reported that the postprandial TG levels in subjects increased after consumption of a meal containing 50 g fat and 50 g starch compared to 50 g starch alone. Martens et al (2014) also observed that the intrahepatic TG levels of subjects decreased after having a high protein-low carbohydrate diet. As for fiber, it was observed that consumption of fiber supplements did not have a significant effect on TG levels (Knopp et al. 1999). This might explain why higher TG concentrations were observed in BA even though BA contained a smaller amount of fiber compared to BAF2. This is because the higher fiber content in BAF2 was unlikely to have an effect on TG concentration. Hence, the increase in TG concentrations observed after BA, BAF1 treatments might be attributed to the higher fat and protein content in BA and BAF1.

Consumption of almonds is known to reduce serum cholesterol levels (Josse et al 2007). Previous studies reported that consumption of high monounsaturated fat diet and the consumption of fiber reduced total cholesterol levels (Garg 1998; Knopp et al. 1999). In this study, consuming BA, BAF1, and BAF2 did not have a significant effect on serum TC concentration when compared to treatment B. This suggests that consumption of almond paste and/or inulin did not have an acute effect on serum TC

level. On the other hand, a high protein diet did not have a significant effect on the total cholesterol levels (Gannon et al. 2003). Hence, the protein present in almond paste might have masked the effect of monounsaturated fat in almond paste and fiber on total cholesterol level. Therefore, further studies are needed to determine the effect of the consumption of almond paste and/or inulin on serum TC level on a long-term basis.

Conclusions

With increasing consumption of almond paste as a filling in sandwiches and pastries, our study clearly demonstrated that the inclusion of almond paste with bread reduces both glycemic and lipidemic responses. Given the nutritional and health values of intact almonds, it appeared that almond paste could also be an additional recommendation for its nutritional effects. Our results showed that there is a significant reduction in glucose and insulin response after consumption of BAF1 due to the highest levels of protein, fat, and fiber in BAF1. Although co-ingestion of bread with almond paste and/or inulin increased TG levels (not reach statistical significance), it did not have an effect on TC levels. Our studies demonstrated that the versatility of almonds. It appears that almonds may have beneficial effects on human health when consumed intact, made into almond paste, and added into a beverage. Further studies will be required to demonstrate the beneficial effects of co-ingesting almond paste and inulin on human health on a long-term basis.

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All authors declare no conflict of interest.

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Table 1. Study meal.

Treatment	Description
Treatment 1 (BA)	Bread + almond paste 15 g
Treatment 2 (BAF1)	Bread + almond paste 15 g + inulin 4 g
Treatment 3 (BAF2)	Bread + almond paste 10 g + inulin 3.8 g
Treatment 4 (B)	Bread (control)

Available carbohydrate content is 50 g (total carbohydrate – dietary fiber)

Table 2. Macronutrient and energy content of the 3 test meals and the white bread control meal.

Test meal	Energy (kJ)	Available carbohydrate (g)	Protein (g)	Fat (g)	Fiber (g)
BA (88.7 g bread + 15 g almond paste)	1357.6	50	11.8	9.8	2.9
BAF1 (88.7 g bread + 15 g almond paste + 4 g inulin)	1357.6	50	11.8	9.8	6.9
BAF2 (89.6 g bread + 10 g almond paste + 3.8 g inulin)	1240.0	50	10.9	7.1	6.2
B (91.4 g)	1005.8	50	9.0	1.7	1.3

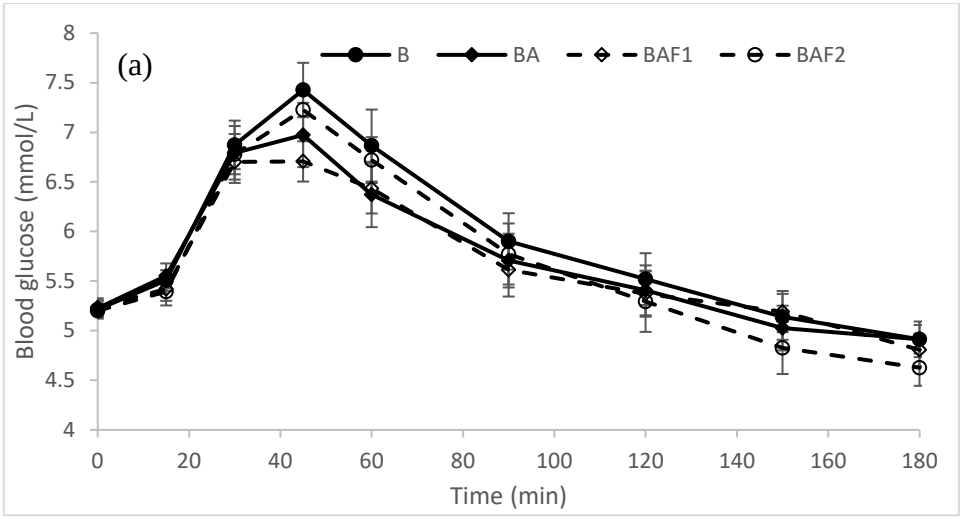
Table 3. Characteristics of the study population.

Variables	Total subjects (*n*=15)
Age (year)	37.8 ± 2.6
Height (cm)	170.3 ± 1.8
Weight (kg)	62.5 ± 1.8
BMI (kg/m^2)	21.5 ± 0.4
WC (cm)	79.8 ± 1.4
HC (cm)	94.5 ± 1.1
FM (%)[a]	24.6 ± 0.9
FM (kg)[a]	15.1 ± 0.7
FFM (kg)[a]	46.3 ± 1.6
SBP (mmHg)	124.7 ± 2.8
DBP (mmHg)	78.2 ± 2.4
FBG (mmol/L)	5.2 ± 0.1

BMI, body mass index; WC, waist circumference; HC, hip circumference; FM (%), fat mass percentage; FM, fat mass; FFM, fat free mass; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose.

Values are expressed as mean ± SD.

[a] Measured by dual-energy x-ray absorptiometry (DEXA).



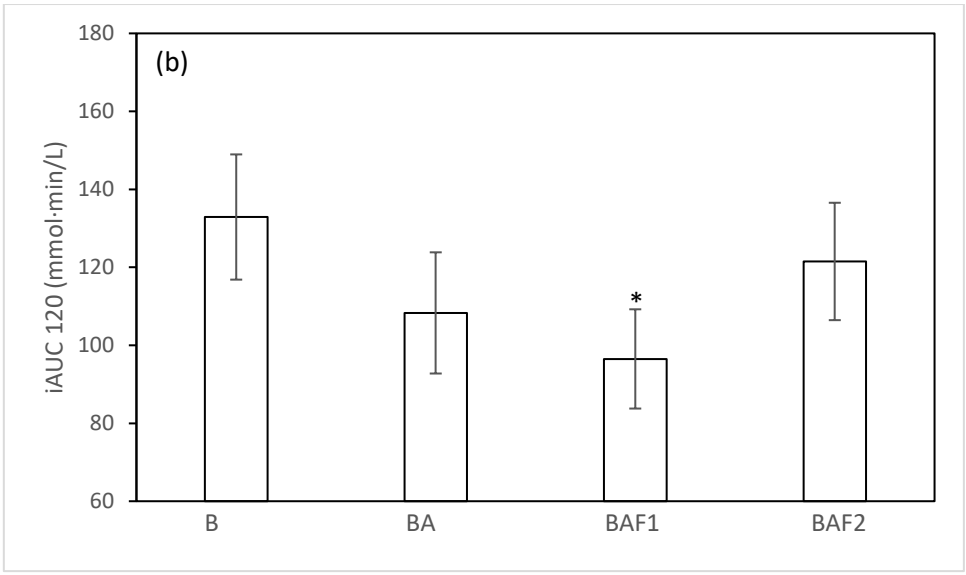
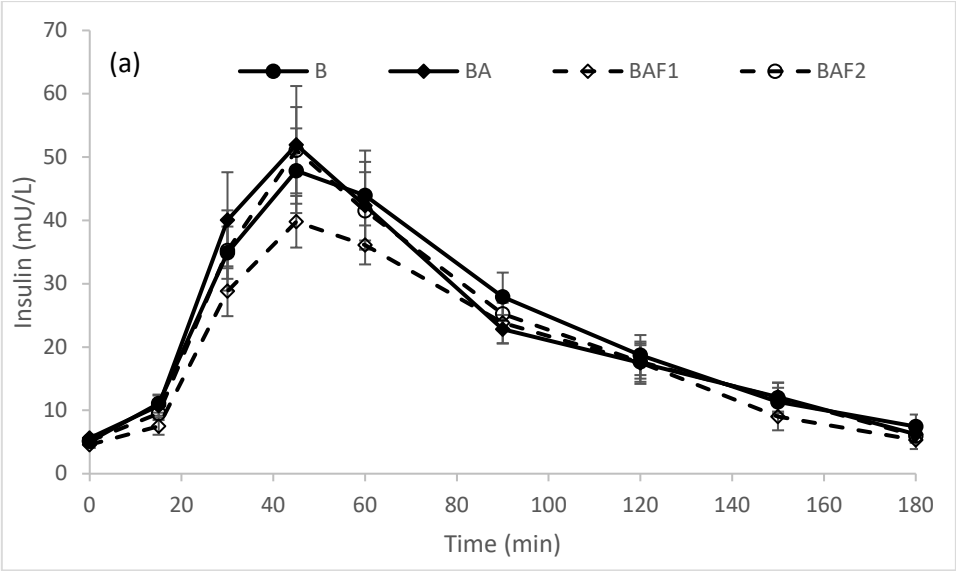


Figure 1. (a) Postprandial blood glucose concentrations in 15 healthy subjects for 3 h after consumption of the 3 test meals and the control white bread meal. (b) Incremental AUC (iAUC) over 120 min period using fasting values as the baseline. * $p < 0.05$.



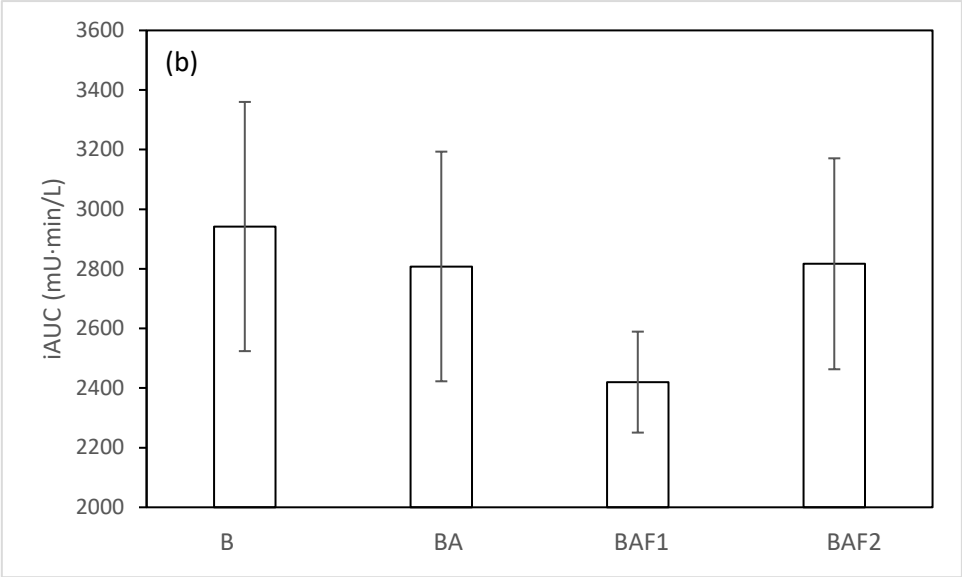
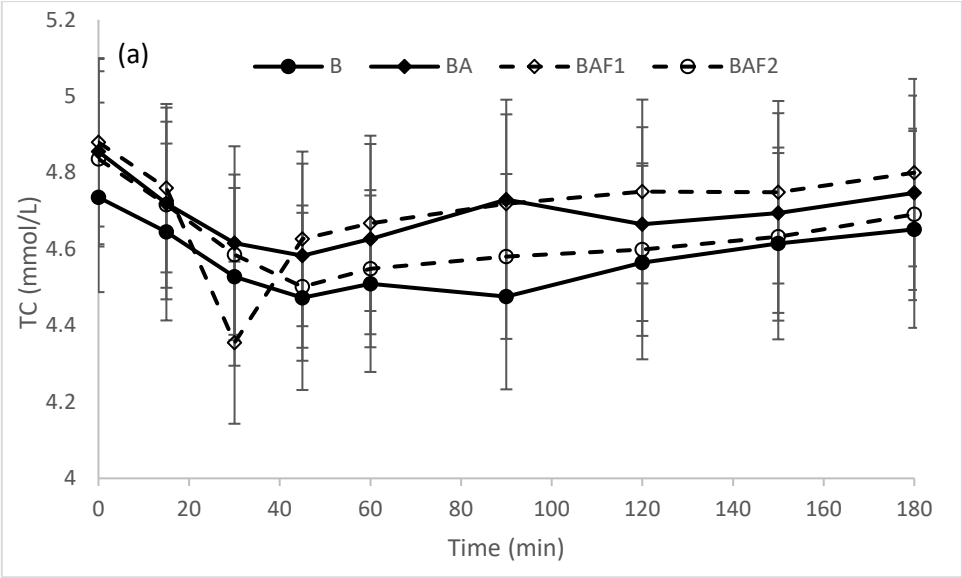


Figure 2. (a) Postprandial serum insulin concentrations in 15 healthy subjects for 3 h after consumption of the 3 test meals and the control white bread meal. (b) Incremental AUC (iAUC) over 120 min period using fasting values as the baseline.



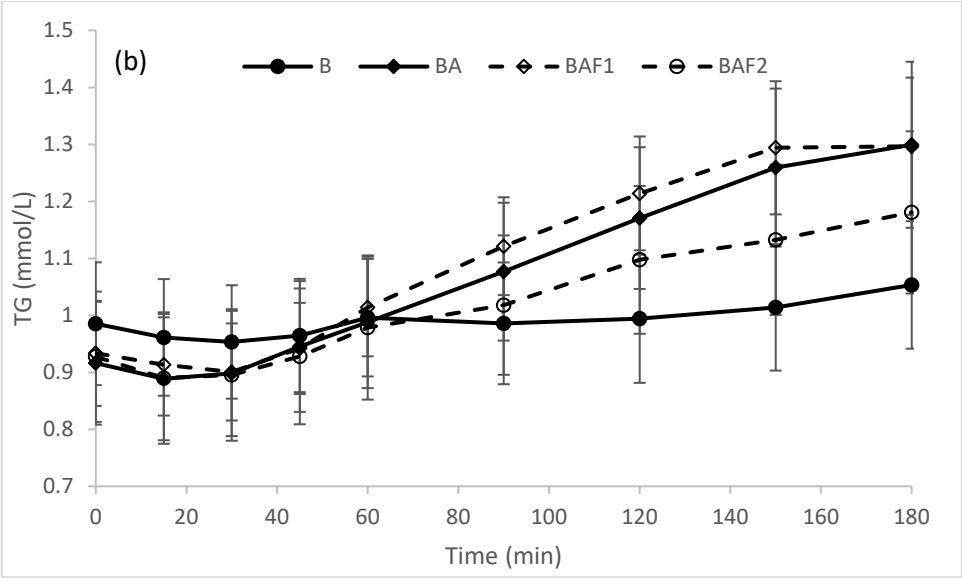


Figure 3. Postprandial serum (a) total cholesterol (TC) and (b) triglyceride (TG) concentrations in 15 healthy subjects for 3 h after consumption of the 3 test meals and the control white bread meal.

Figure captions:

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