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Short Communication

Bread buns or slices? variations of bread shape modifies ad libitum intake of bread and toppings

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ABSTRACT

The size and shape of foods are geometrical textural properties that have been shown to influence food intake. Changing shapes and sizes of carrier food such as bread influences the spreadable surface area and this may affect the amount of toppings used. In a cross-over study, 37 participants (11 males, 24 ± 7 years old, BMI of 23 ± 3 kg/m^2) consumed three times an ad libitum breakfast consisting of either small buns (SB: 34 g per unit), large buns (LB: 47 g), or squared sandwich slices (SA: 36 g), similar in nutritional composition. Participants were free to use four kinds of toppings similar in energy density (2.3–2.4 kcal/g): apple syrup, jam, cream cheese, and egg salad. The ratio bread(g):topping(g) differed considerably (1:0.49 for SB; 1:0.53 for LB; and 1:0.63 for SA, $p < 0.001$), but total meal intake did not differ (g or kcal) $p = 0.27$. In sum, the meal with SA leads to relatively higher intake of toppings and lower intake of bread, whereas the meal with small buns (SB) leads to relatively lower intake of toppings and higher intake of bread. Changing surface areas by shapes of carrier foods can be used to manipulate the amount of toppings, condiments or sauces and thereby modulate the macronutrient and energy intakes within a meal or snack.

1. Introduction

It has been widely shown that textural food properties influence eating rate and thereby food consumption (Bolhuis & Forde, 2020). A number of studies showed that harder foods are consumed slower which ultimately led to lower energy intake, whereas softer or more lubricated foods increase the consumption speed which may result in higher food intake (Bolhuis et al., 2014; Pey Sze Teo et al., 2022; Wee et al., 2018). Therefore, food texture can be modified to design foods that either promote or moderate energy intake.

Food textural parameters can be divided in bulk (rheological) properties, surface-related (tribological) properties and geometrical properties. Each parameter has a distinct influence on oral processing behaviors. Geometrical food properties includes the size and the shape of the foods. An advantage of changing geometrical food properties is that it may have less impact on the liking of the foods compared to more structural changes like hardness, viscosity or lubrication which are considered to have more impact on the sensory appeal.

It has been repeatedly shown that larger unit sizes of foods promote greater intake compared to similar foods in smaller unit sizes. For example, smaller cookies resulted in less intake than similar larger cookies (Kerameas et al., 2015), similar effects were seen for 8 g vs.32 g pieces of brownies (Vandenbroele et al., 2019), bars vs. nibbles (Weijzen et al., 2008), and pieces of carrot vs. whole carrots (Liem & Russell, 2019). An explanation could be that larger unit sizes are consumed faster due to greater bite sizes (Hutchings et al., 2009; Weijzen et al., 2008), and higher eating rates leads to higher food intake (Robinson et al., 2014). In similar way, food shape also affects oral processing, carrots in cubes required less chewing than carrots julienne (van Eck et al., 2019). The shape of food is likely to affect bite sizes and therefore eating rate. Besides influences on oral processing, shape and size may also effect the perception of a portion size and this perception mediates food intake (Vandenbroele et al., 2019). For example, multiple smaller units may be perceived as more food than less larger units (Lewis & Earl, 2018), so-called 'numerosity heuristic' (Pelham et al., 1994). In similar way, food shapes with more surface may visually perceived as more food compared to shapes that are more condensed.

Many foods are consumed in combinations with other foods. Composite foods consist of carrier foods (mostly a carbohydrate-containing source) and condiments (e.g., toppings, spreads, fillings, and sauces).

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Adding condiments to a carrier food can enhance palatability and greatly increase the lubrication of the composite material, thus speeding up the eating rate (van Eck, Hardeman, et al., 2019). Many condiments are high in energy density (e.g., butter or sauces) and will thereby increase the total energy density of the composite foods. This means that condiment addition stimulates energy intake by a) speeding up the eating rate by assisting in lubrication and b) increase the energy density of the food. Both higher energy densities (kcal/g) and higher eating rates (g/min) encourage energy over-consumption and adiposity (Hall et al., 2019; Rolls et al., 2020; Teo et al., 2021).

By changing the shape and size of carrier food, the surface area available for condiments will be modified and consequently it is expected to influence the amount of topping added (Eck et al., 2020). However, little research has been performed on the influence of shape and size with self-application of a choice of toppings. The aim of the presence study was to investigate the effect of size (small vs. large buns) and shape (small bun vs. squared sandwich slice) on bread intake, condiment intake, total energy intake and eating rate.

2. Materials and methods

2.1. Design

The study consisted of an ad libitum cross-over trial with three conditions, in which participants consumed 1. small buns (SB), 2. large buns (LB), or 3. squared sandwich slices (SA) with condiments during breakfast. During each condition, participants could choose from the same two sweet and two savory condiments, similar in energy densities (2.3–2.4 kcal/g). Participants consumed ad libitum and were free to apply toppings of their choice. Participants attended three breakfast sessions, approximately once a week and with a minimum of two days between each test day.

2.2. Participants

Participants were recruited from Wageningen and surroundings using social media, printed posters, printed flyers, and mailing lists. Participants were selected to be bread consumers (at least once a week, self-reported) and they should not dislike white buns, white sandwich slices and more than one of the toppings (a rating of 5 or higher on a 9-point Likert scale). They also had to fulfill the following criteria: aged between 18 and 55 years, speak and understand the Dutch language, BMI between 18.5 and 30 kg/m^2, and had a good general health and appetite (self-reported). Participants were excluded from the study if they were allergic or had an intolerance to any of the ingredients of the food products, had difficulties with swallowing, chewing, or eating in general, had taste, smell or eating disorders, had dental problems or had braces or oral piercings. After the screening, 42 participants were selected to participate in this study. Two of these participants were dropped out since they attended only one test session. Three participants were excluded from data analysis, as two participants consumed large quantities of food and alcohol less than twelve hours prior to the test sessions (self-reported) and one participant did not understand the Dutch language well enough and was not compliant with the guidelines and instructions.

The remaining 37 participants (11 males, 24 (SD 7) years old, BMI of 23 (SD 3) kg/m^2) completed the study. Participants gave written informed consent before the start of the study. The social Science Ethics Committee of Wageningen University concluded that the proposal deals with ethical issues in a satisfactory way.

2.3. Test products

Three types of white breads with different shapes and sizes were used (Jumbo private label, the Netherlands) as presented in Fig. 1. The three types of breads had similar ingredients and nutritional compositions, but had different dimensions and spreadable surface areas, see Table 1. Bread was stored in the freezer for a maximum of two weeks. One hour prior to each test session the breads were defrosted to room temperature. The condiments used were: strawberry jam (2.26 kcal/g) (Hero, the Netherlands), apple-pear syrup (2.39 kcal/g) (GIJS, the Netherlands), herbal cream cheese (2.36 kcal/g) (Paturain, the Netherlands), and egg salad (2.34 kcal/g) (Jumbo private label, the Netherlands). To present

Table 1
Means (SD) of weights, heights, spreading surface areas, amount of served units, and energy densities of the used bread units.

	Small round bun (SB)	Large round bun (LB)	Squared sandwich slice (SA)
Weight per unit (g)	33.8 (1.4) (n = 592)*	46.6 (2.0) (n = 296)	35.7 (1.1) (n = 592)
Height (cm)	5.13 (0.17) (n = 20)	5.03 (0.43) (n = 20)	1.40 (0.03) (n = 20)
Spreading surface area per unit (cm^2)	38.6 (1.1) (n = 20)	78.2 (2.4) (n = 20)	117 (2.6) (n = 20)
Served units (n)	16	8	16
Energy density (kcal/g)	2.61	2.52	2.52

*n indicates the number of measurements.

Fig. 1. Pictures of the bread units used, Large Bun (LB), Small Bun (SB) and Squared Sandwich Slice (SA).

all condiments in similar way and to remove cues of brands and packaging, condiments were served in plastic transparent cups of 200 mL filled with approximately 150 g condiment. All condiments were stored in the refrigerator. One hour prior to each test session, the condiments were exposed to room temperature.

2.4. Test day procedure

Participants were instructed not to eat or drink twelve hours prior to their test sessions (except for water). There were two breakfast sessions per day, participants were scheduled for either 8 AM or 9 AM. At the beginning of the test sessions, the participants were told that they were not allowed to eat the top and bottom of a bun separately and that it was not allowed to take any of the bread and toppings home. Before the participants entered the sensory booths, the booths were equipped with two cups of each topping, four identical knives (one for each topping), a drinking glass (pre-weighed), a carafe filled with approximately 9 dl water (pre-weighed), and a plate. After participants rated their appetite (hunger, fulness and thirst), they received a large plate with pre-weighed bread (Table 1). The buns were pre-cut so that every bread had the same spreading surface area. Participants were instructed that they could eat as much bread and toppings as they wanted until they got comfortably full. They were instructed that it was allowed to leave left overs and that they did not need to consume whole bread units. In addition, participants were instructed that they could ask for more bread, toppings, and water if they wanted, however this did not occur because the served foods were never completely finished.

Under each bread unit was a small piece of paper on which the participants could indicate which condiment they used. This was needed to be able to link the condiments to the number of bread units. Just before participants took the first bite, they were asked to click on a button in the questionnaire to start the timer. After the last swallow, participants had to click again on this button which stopped the timer. The timer incorporated in the questionnaire, which was not visible for the participants, registered the total time that the participants spent consuming the meal. Eating rate (g/min) was calculated by dividing the total consumption time in by the total consumption in grams. After the meal, participants were asked about their main reason why they terminated consumption. They could choose from "I was full", "I always eat the same portion", "The bread was not tasty anymore", "The toppings were not tasty anymore", and "other". Finally, participants were asked to rate their appetite, bread liking, and the liking of each topping they had consumed, using a 100 unit visual analog scale (VAS) anchored with "not at all" and "extremely". Data were acquired by Qualtrics survey software (version April 2022, Qualtrics).

2.5. Data analyses

Statistical analyses were performed by using IBM SPSS Statistics version 28. Data are presented as means with standard deviations. Means of dependent variables of the three breakfast conditions were compared by Repeated Measures General Linear Model. One-way ANOVA was used to compare intake of the four different toppings calculated per bread unit. LSD post hoc comparisons were used. Pearson correlations were used to assess correlations between dependent variables.

3. Results

3.1. Total breakfast food intakes

The amount of bread intake (g) during breakfast was influenced by the bread type ($p_{main} = 0.004$). SA were consumed in 13 % lower amounts than SB ($p_{LSD} = 0.001$), whereas the consumption of LB was in between both (Fig. 2). The mean(SD) number of units consumed was 4.5 (1.3) for SB, 3.1(0.9) for LB, and 3.7(1.1) for SA ($p_{main} < 0.001$).

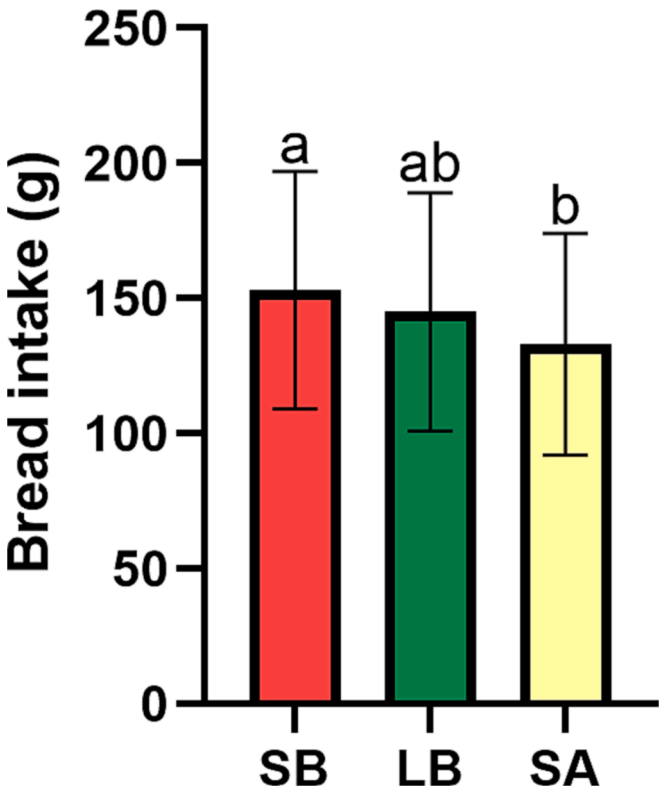

Fig. 2. Mean (SD) bread intake of the three different breakfast sessions. SB = small buns, LB = large buns, SA = squared sandwich slices. [a,b]Different letters means significant differences after post hoc comparisons.

Total food intake during breakfast (bread + toppings) did not differ between conditions in gram (SB: 225(65) g; LB: 221(69) g; SA: 215(70) g, $p_{main} = 0.60$) or in kcal ($p_{main} = 0.27$) (Fig. 3). However the ratio bread:toppings differed considerably, which was 1:0.49 for SB; 1:0.53 for LB; and 1:0.63 for SA ($p_{main} < 0.001$), where relatively less topping per unit was consumed with SB and LB compared to SA ($p_{LSD} < 0.001$) (Fig. 4). Mean water intake was between 255 and 277 g and did not differ between conditions ($p_{main} = 0.44$). The breakfasts differed in eating rate (g/min) ($p_{main} = 0.032$), where breakfast with SA were consumed slower (21.4(7.5) g/min) compared to both SB (23.4(7.5) g/min) and LB (24.3(8.6) g/min) ($p_{LSD} < 0.038$). The eating rates in the LB and SA conditions were positively correlated to total food intake (g) for LB ($r = 0.56$, $p < 0.001$) and SA ($r = 0.37$, $p = 0.02$). A trend was

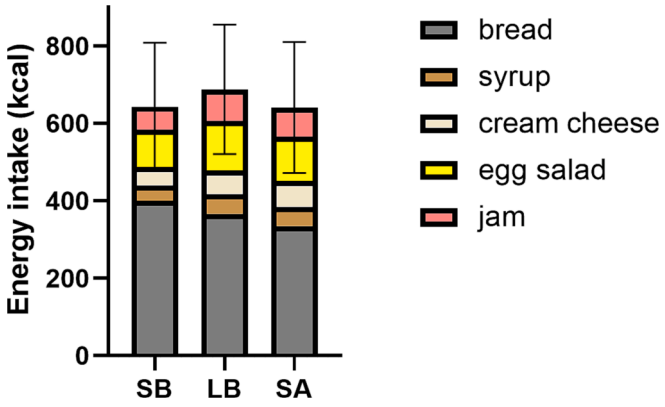

Fig. 3. Mean (SD) of total energy intake of the three different breakfast sessions. SB = small buns, LB = large buns, SA = squared sandwich slices. The ratio bread:toppings was higher for SA compared to both SB and LB conditions ($p_{LSD} < 0.001$).

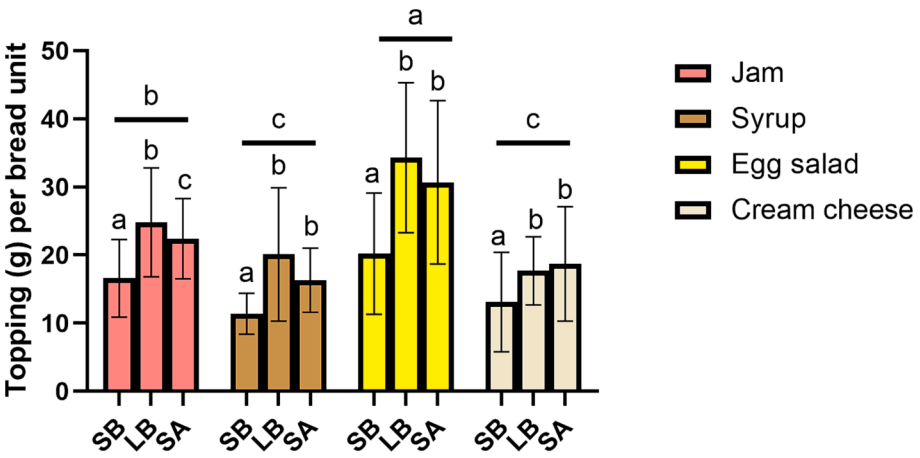

Fig. 4. Mean (SD) of topping intake (g) per bread unit. SB = small buns, LB = large buns, SA = squared sandwich slices. Means (SD) were based on (Egg salad: SB n = 56; LB n = 37; SA n = 36); (Jam: SB n = 45; LB n = 31; SA n = 42); (Cream cheese: SB n = 40; LB n = 28; SA n = 35); and (Syrup: SB n = 29; LB n = 19; SA n = 25).

observed for SB (r = 0.28, p = 0.09).

3.2. Topping intake

When calculated per bread unit, mean total topping was highest for LB with 24.5(9.9) g/unit, slightly less for SA with 22.4(8.0) g/unit and least for SB with 16.4(7.5) g/unit ($p_{main} < 0.001$). Analyzing the separate toppings shows that intake (g) per unit was always lower for SB compared to both LB and SA (all $p_{main} < 0.02$) (Fig. 4). Egg salad was most frequently chosen (SB n = 56 buns; LB n = 37 buns; SA n = 36 slices), followed by jam (SB n = 45; LB n = 31; SA n = 42) and cream cheese (SB n = 40; LB n = 28; SA n = 35). Apple syrup (SB n = 29; LB n = 19; SA n = 25) was the least popular choice. The self-chosen portion sizes of toppings per bread unit differed between type of toppings ($p_{main} < 0.001$ for all three breakfast conditions). Egg salad was consumed in the largest portions, followed by jam, followed by both syrup and cream cheese.

3.3. Appetite and hedonics

The state of hunger, fullness and thirst did not differ between conditions before or after the breakfast meals (Table 2). The liking of the toppings assessed after the three different breakfast meals shows that cream cheese and egg salad were more liked than strawberry jam and apple syrup. The type of bread with which the topping was served did not influence the liking of the topping. Plain SA was liked less than plain SB and LB. However, liking plain SA was not correlated with intake of SA bread (r = -0.16, P = 0.34), and seemed slightly negatively correlated with total intake (SA + topping) (r = -0.29, P = 0.08). Similarly liking of plain SB was not correlated with intake of SB bread or total intake (both p > 0.94) and liking plain LB was not correlated with intake of LB bread or total intake (both p > 0.50). Liking of the different plain breads were also not correlated with their ER (all p > 0.21). Participants indicated they stopped eating because they were full in 91 % of the sessions, they did not like the bread anymore in 5 % of the sessions, they always eat the same portion in 3 % of the cases, or they did not like the toppings anymore in 1 % of the cases.

Table 2
Mean (SD) appetite and liking ratings on a 100 unit VAS.

	SB	LB	SA	P
Hunger				
Before	54 (18)	54 (21)	53 (20)	0.90
After	15 (17)	13 (18)	12 (13)	0.63
Full				
Before	19 (19)	19 (16)	21 (21)	0.72
After	68 (19)	71 (16)	63 (22)	0.06
Thirst				
Before	58 (23)	56 (19)	50 (19)	0.29
After	25 (23)	23 (25)	27 (18)	0.51
Liking				
Plain bread	54 (19)[a]	55 (16)[a]	39 (19)[b]	<0.001
Apple-pear syrup	58 (16)	64 (15)	50 (20)	0.43
Strawberry jam	58 (16)	62 (16)	60 (16)	0.93
Herbal cream cheese	71 (15)	68 (15)	72 (11)	0.33
Egg salad	67 (14)	69 (16)	67 (13)	0.89

4. Discussion

The present study shows that shape of bread influenced consumption of bread and toppings. Bread intake for sandwich slices was less compared to buns similar in weight (SA vs. SB), and the ratio bread: toppings differed considerably. Relatively less bread and more toppings were consumed in the sandwich condition compared to the buns. The size of the buns (SB vs. LB) did not significantly affect total bread intake and bread: toppings ratio.

Participants were free to use the choice of toppings they preferred and could apply as much as they desired. Sandwich slices and small buns were about the same weight (36 g and 34 g per unit), however the spreading surface area of sandwich slices was around three times larger (117 cm^2 vs. 39 cm^2). This larger surface area led to 36 % more topping intake per bread unit. In line with the present results, an earlier study showed that squared shaped crackers were associated with larger intakes of dipped cream cheese compared to finger shaped crackers with a smaller surface area (van Eck et al., 2020). This means that the surface area of carrier foods is an indicator of the amount of condiments or toppings used.

In addition to effects of spreadable surface area, also differences in bread texture could have influenced the amount of toppings that were applied. It makes sense that dryer textures may lead higher amounts of topping to stimulate lubrication that facilitates oral processing and consumption. No textural measures were executed in this study, but the slices could have been slightly more dense and dry which may partly explain the increased topping addition.

When looking at the bread consumption separately, sandwich slices were on average consumed in lower amounts than buns. This may have several causes. First of all, the larger amounts of toppings on the sandwiches compared to the buns may have resulted in earlier satiation. Another explanation could be that breakfast with sandwich slices were

consumed at 11 % lower eating rates compare to the breakfasts with buns, and eating rate is negatively associated with food intake (Robinson et al., 2014). This is probably explained by the shape of the food. Unpublished research of our lab showed that plain buns were consumed considerably faster than plain bread slices, due to larger bites sizes explained by the increased height of the bread buns. Lastly, plain sandwich slices were less liked than buns, possibly explaining the lower intakes of plain sandwich. However, differences in liking between the bread disappeared when bread were consumed with toppings, and the liking of the plain sandwiches were not correlated to bread intake, or eating rate in the sandwich condition.

A strong point of the study is the self-application and free choice between four types of toppings. This is more closely to real life settings compared to many other ad libitum intake studies using fixed meals, and this could prevent participants terminate consumption due to boredom. Two sweet and two savory toppings were chosen based on similar energy densities. Interestingly, these toppings led to different portion sizes of toppings per bread unit. Participants used largest portions of the egg salad, followed by jam, and smallest portion sizes were observed for cream cheese and apple pear syrup. This could be due to the physical food properties such as spreadability or lumps in the egg salad and jam which makes the portions automatically larger. In addition, also sensory food properties such as flavour intensity could have played a role here. Stronger flavors or taste intensities may results in smaller portion sizes (Bolhuis et al., 2011). More research is needed to investigate the effect of physical and sensory properties of foods on the self-chosen portion sizes.

In conclusion, bread shape (sandwiches vs buns) influenced the ratio bread:toppings that was consumed, but did not influence total food or energy intake in this study. Changing the shape of carrier foods in a way that reduces the surface areas may unconsciously decrease the consumption of high energy dense condiments, sauces and toppings. This indicates that the shape of carrier foods may alters the ratio of (macro) nutrients that are consumed, and could be used to steer healthy food consumption.

CRediT authorship contribution statement

Dieuwerke P. Bolhuis: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing. **Aaron Wouters:** Investigation, Methodology, Software. **Lise A.J. Heuven:** Conceptualization, Methodology, Software, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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