Food and Humanity 5 (2025) 100802

Contents lists available at ScienceDirect

Food and Humanity

journal homepage: www.editorialmanager.com/foohum/journal_overview.html

Development and consumer perceptions of a snack machine producing customized or personalized on-demand bakery products

Jenni Lappi [a,*], Anne Arvola [b], Alex Calton [a], Adil Umer [a], Saara Vanhatalo [a], Pekka Kilpeläinen [a], Kyösti Pennanen [b], Nesli Sozer [a]

[a] VTT Technical Research Centre of Finland Ltd., P.O.Box 1000, 02044, Finland
[b] University of Vaasa, P.O.Box 700, Vaasa 65101, Finland

ARTICLE INFO

Keywords:
Consumer perceptions
Snacks
Vending machine
Food customization
Food personalization

ABSTRACT

Vending machines typically offer unhealthy snacks but have underutilized potential to provide healthier options on demand. This paper introduces a prototype snack machine with two separate versions of function for producing either a) customized or b) personalized fresh bakery products. The development of the machine and user studies assessing its usability and added value are discussed. In the first study (n = 81), consumers evaluated food customization by adding extra protein or fiber. In the second study (n = 23), food personalization was explored through snack recommendations based on dietary preference data from an integrated personalization platform. Majority of consumers (64–91 %) in both studies had positive attitudes towards the snack machine. Usability ratings for the machine and personalization platform were favorable, with all mean scores significantly above neutral. In the first study, 62 % of participants used the customization options. The primary added value was the ease of snack acquisition compared to participants' current situation. Fresher snacks were perceived as an advantage. In the second study, the personalization function was highly appreciated when 91 % selected the recommended snack, with 87 % finding the recommendations useful. Participants believed the machine would add value by saving time, making snack acquisition easier, offering healthier, higher-quality options, and allowing them to influence type of snacks. These findings support further development of such machines to improve access to fresh and healthy snacks, especially with the new personalization function. Larger studies involving frequent vending machine users are needed to assess commercial potential and broader applicability.

1. Introduction

Over the past decades, energy intake from snacks and snacking frequency have increased (Bailey, 2022; Kant & Graubard, 2015; Ovaskainen et al., 2010). Snacking especially outside home is associated with consuming unhealthy snacks (Hess et al., 2016; Ziauddeen et al., 2017). Somewhat contradicting current unhealthy snacking habits, consumers claim to prefer snacks that are tasty and convenient, suppress hunger, and may aid in weight management (Enriquez & Gollub, 2023). Convenience is a feature that vending machines could provide for snacking, especially during busy days. However, vending machines are widely known for offering nutritionally poor snacks that are high in fat, saturated fat, salt, and sugar (Grech et al., 2017; Lasala et al., 2022; Park & Papadaki, 2016). Additionally, 95 % of vending machine sales come from drinks (Lindner, 2024), even though solid snacks are generally more satiating and healthier. For instance, nutrient-dense food groups like fruits, vegetables, whole grains, yoghurt, nuts, and seeds can be considered healthy snacks when not used as meal replacements (Hess et al., 2016). There have been successful efforts to promote consumers' healthier solid snack choices in vending machines by simply limiting the availability of high-calorie snack options (Bos et al., 2018) or increasing the selection of healthier ones while maintaining sales (Evans et al., 2023).

An alternative approach could be to allow consumers to customize their snacks to make them healthier. Food customization enables consumers themselves to easily add or omit ingredients from a product or meal according to their immediate preferences. One of the most common examples of customization in vending machines is a basic coffee machine found in offices and public spaces like transportation hubs. These machines allow consumers to choose from various coffee options

* Corresponding author.
E-mail addresses: jenni.lappi@vtt.fi (J. Lappi), anne-kristiina.arvola@uwasa.fi (A. Arvola), alex.calton@vtt.fi (A. Calton), adil.umer@vtt.fi (A. Umer), saara.vanhatalo@vtt.fi (S. Vanhatalo), pekka.kilpelainen@vtt.fi (P. Kilpeläinen), kyosti.pennanen@uwasa.fi (K. Pennanen), nesli.sozer@vtt.fi (N. Sozer).

https://doi.org/10.1016/j.foohum.2025.100802
Received 16 January 2025; Received in revised form 10 July 2025; Accepted 11 September 2025
Available online 13 September 2025

and decide whether to add or reject extra sugar and milk, with the coffee made on-demand.

However, customization by simply omitting unhealthy ingredients can lead consumers to underestimate calory intake, which may have negative consequences on a healthy diet (Besharat et al., 2021). Therefore, a different approach – customizing snacks by adding healthy ingredients – might be more effective. A few years ago, Vehmas et al. (2019) were the first to study consumer perspectives on customization when they co-developed a concept of a healthy snack machine (Vehmas et al., 2019). The participants found the idea of smart food manufacturing of healthy and customized snacks interesting. They expressed interest in buying products that could be eaten on-the-go and emphasized the importance of having healthy options available in vending machines (Vehmas et al., 2019). To demonstrate the concept's practical functionality, a snack machine prototype producing healthy liquid and spoonable snacks with the customization possibility of adding extra fiber or protein was developed in a further study (Vehmas et al., 2020). Consumers experienced the prototype generally positive, and many indicated interest in using a similar machine in the future if the option would become available.

Although a recent review article suggested using smart vending technologies to customize products for healthier choices (Stoyanov, 2021), customization of freshly-baked snacks in vending machines remains rare. Typically, traditional vending machines offer only pre-defined snack options with long shelf-lives. However, some solutions for on demand snacks in vending machines do exist. For instance, vending machines like (just baked smart bistro), (Bake Xpress) and (Fizza) provide consumers with heated meals or snacks prepared from frozen or refrigerated ready-made options at the point of purchase. Unfortunately, these machines predominantly offer unhealthy choices and do not allow on-site customization. Similarly, the (BreadBot), an automated baking machine, provides fresh bread made from scratch, but it also lacks customization possibility. Given the scarcity of customizable solid snacks in vending machines, our aim was to develop a vending machine that offers fresh snacks with healthy features, baked from scratch, and allows consumers to customize their orders.

Beside food customization, personalized nutrition has gained significant interest in recent years. The more specific term "personalized food" focuses on food designed and tailored to individuals based on their pre-defined specific needs (Ueland et al., 2020). Food personalization considers a wide range of consumers' need aspects, including dietary requirements, taste and texture preferences, and other value-related determinants (Derossi et al., 2020; Ueland et al., 2020). Unlike simple customization by consumers, food personalization goes beyond and uses various data sources to tailor food products to individual characteristics or provide personalized recommendations. One of the easiest ways of food personalization involves blending the right ingredients to create food for a specific group of consumers, optimizing for their individual dietary requirements and preferences (Derossi et al., 2020). Also, artificial intelligence (AI) is currently used to analyze consumer's purchase history data, and to give personalized recommendations based on past purchases, even in vending machines (an example is Cloudpick AI-powered solutions). However, achieving mass customization in food production (Calegari & Fettermann, 2018) and large-scale production of personalized food that meets consumers' nutritional needs and preferences (Ueland et al., 2020) is challenging, especially for fresh, on demand snacks. Vending machines could offer a new solution by producing fresh, customized or personalized food at the point of purchase for small or medium-sized communities.

In addition to developing a prototype snack machine that produces freshly baked snacks customized by consumers on demand, we further developed the machine to support automized, data-based personalized food production. The initial version of the snack machine allowed for on the point of purchase customization (options to select extra protein or fiber). The second functional version was modified to use pre-collected data on consumers' dietary requirements and preferences. Based on this data, the machine provided a personalized snack recommendation for the user. We conducted separate user studies for both machine versions using small convenience consumer samples and questionnaires.

The aims of these studies were to understand users' attitudes towards the snack machine, assess the usability of the machine and the personalization platform used for data collection for the second machine version, as well as to determine whether the machines offer added value for consumers through their customization or personalization functions. We hypothesized that majority of participants in the user studies would show positive attitudinal reactions towards both functional machine versions.

2. Material and methods

2.1. Development of the on-demand snack machine prototype and snacks

A starting point for both snack machine development was that they should produce fresh bakery products. The development of the machine prototype for on-demand production of fresh bakery snacks consisted of a hardware and a user interface (UI). The hardware is described in detail in the Supplementary material. A user can apply the machine via a graphical UI and a touch screen. Two different versions of the UI were developed. The first version was for customized snack production, that is, it provided consumers with the opportunity to enrich the snack with healthy ingredients (dietary fiber and protein). For food customization, a user must make selections on consecutive UI screens. The flow of the selections is described as a decision tree in Fig. 1. First, a user chose either a sweet or a savory snack. For a sweet snack there were three different flavor options but for the savory snack there was only one option. Then, the user had to choose whether to add protein and fiber in the snack, and the type of possible extra protein and fiber. On the last screen, the user either placed the order or was still able to modify his/her previous selections before making the final order.

The second version of the UI provides an opportunity to personalize the snacks according to consumers' data, such as dietary requirements and preferences for domestic ingredients and taste and texture of snacks. For food personalization, the initial UI was changed for selection of savory snack options (Fig. 2), to possibly improve the image of healthfulness of these snacks. Of these, the most suitable one or ones were highlighted as recommendations based on the consumer's data. The machine was connected to the internet by utilizing Wi-Fi which enabled remote update of the software.

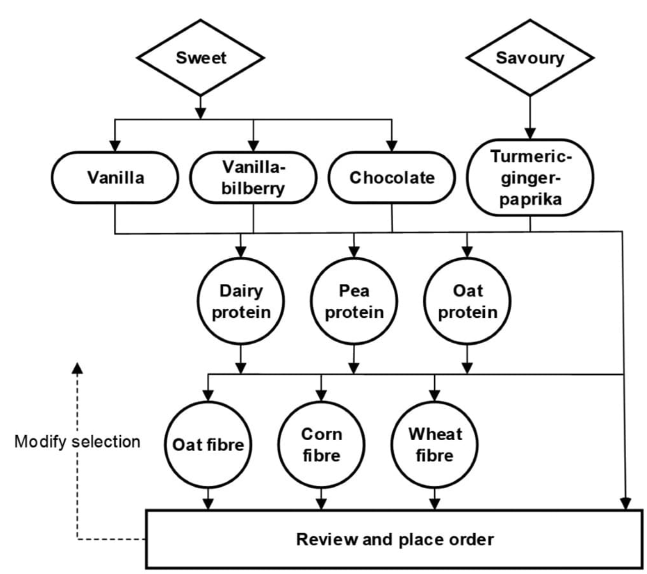

Fig. 1. Decision tree of the user interface of product customization (i.e. version tested in the first user study).

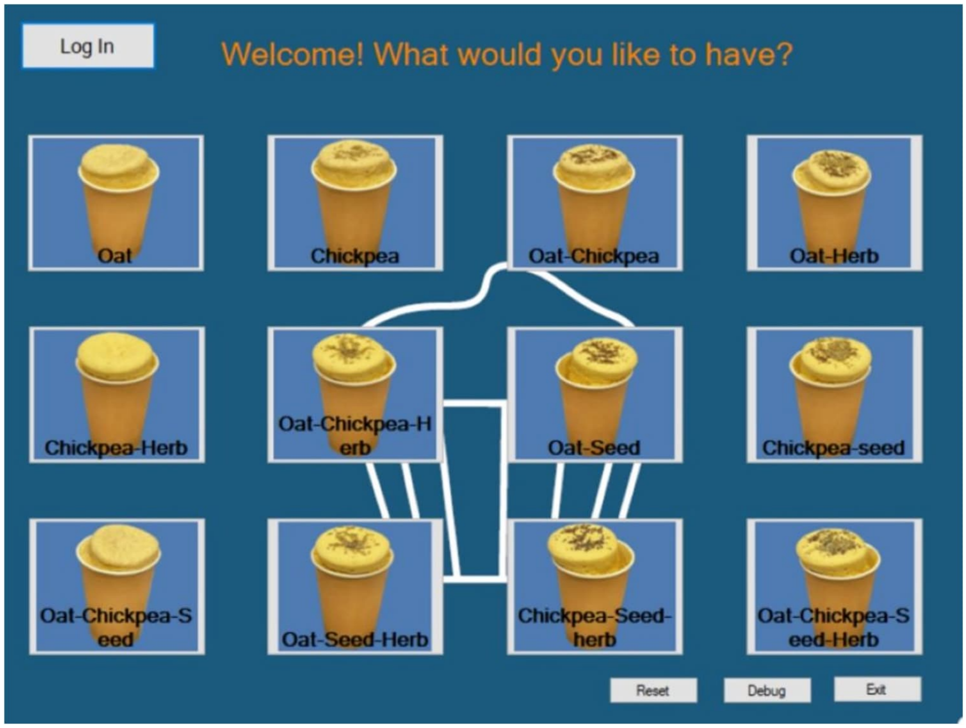

Fig. 2. Graphical user interface for food personalization shows available snack options.

2.1.1. Development and utilization of a personalization platform

To enable personalization features in the snack machine for the consumers, a personalization platform was developed as described in Supplementary material. Users can apply the platform to create their personal profiles based on their preferences and needs. In practice, the user is asked to complete a questionnaire with following themes: dietary requirements (such as allergens, lactose-free, gluten-free, vegan, FODMAP-free diet, etc.), goal setting (such as reducing salt intake, improving fat quality in the diet, reducing sugar intake, etc.), and preferences for snacks (including preferences for snacks with or without herbs, and preference for texture, whether smooth or coarse). The information gathered in the platform enables the personalized snack production while consumer is later using the snack machine (unlike customization where users select ingredients for the snack). The platform does not gather personal information, but a user's personal email address is required for the administrator to create the user account.

Within the personalization platform, specific tags are associated with each answer to the questions and a snack recipe (Fig. 3). For instance, if a user had answered to prefer snacks with a smooth texture, the personalization platform reviewed the recipes associated with the smooth texture tag and added those recipes to the personalized list of recommendations for the specific user. It is to be noted that a recipe is only added to the user's personalized recommendation list if it meets all the preferences inputted by the user in the platform. Additionally, the platform generates individual four-digit pin code for each user. When a user logs in to the snack machine using the provided pin code, the snack machine sends a request to the personalization platform to fetch the list of personally tailored recommended recipes (Fig. 3). The snack machine supported recipes related to twelve different snack options (Fig. 2). The recommended recipes were highlighted as snack recommendations on

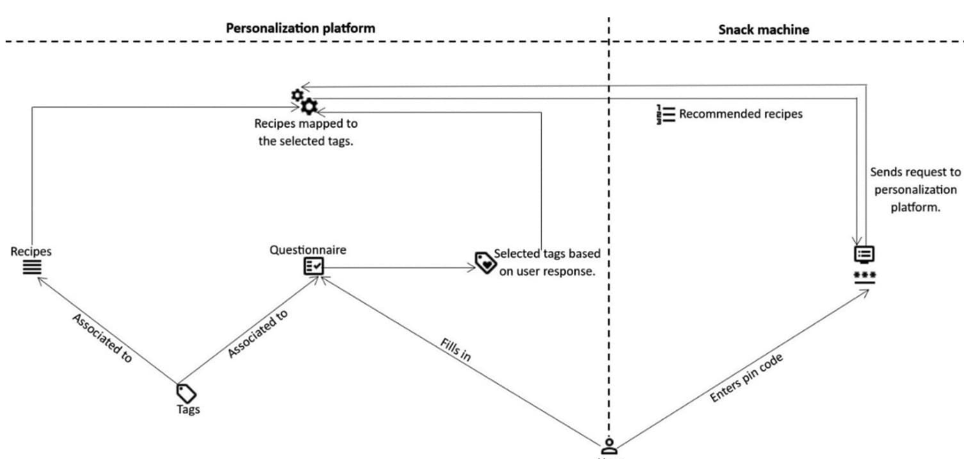

Fig. 3. Recipe recommendation flow for the product personalization in the snack machine (i.e. second version of function tested in user study 2.). The user creates a profile on the personalization platform, which is used to recommend suitable recipes (visualized as recommended snacks on the user interface) that match the user's profile.

the snack machine's UI to the user.

2.1.2. Snack development

The snack type (cake-in-a-cup) and ingredients were chosen based on technological feasibility that was dictated by the snack machine. A sweet or savory warm snack was developed and tailored on-demand by combining a variety of dry ingredients with vegetable oil and water, mixed and microwave-cooked. Dry ingredients were chosen for safe storage at ambient temperature, easy dispensing by rotating augers, clump-free dispersion into liquid, and requiring minimal mixing time and intensity to form into batter. Dry ingredients included extruded oat endosperm flour (Raisio Nutrition Ltd, Finland), whole-grain oat flour (Helsingin Mylly Oy, Järvenpää, Finland), chickpea flour (Foodin Oy, Jyväskylä, Finland), resistant corn dextrin (Nutriose FM06, Roquette Frères, Lestrem, France), table sugar (Suomen Sokeri Oy, Kantvik, Finland), lactose-free semi-skimmed milk powder (Eila, Valio Oy, Helsinki, Finland), whole egg powder (Munax Oy, Laitila, Finland), table salt (Meira Oy, Helsinki, Finland), baking powder (sodium pyrophosphate; sodium bicarbonate; citric acid; corn starch, Meira Oy, Helsinki, Finland), cocoa powder (D-11-CK, ADM International Sàrl, Rolle, Switzerland), activated whipping emulsifiers (Emulpals 115 and 117, Palsgaard A/S, Juelsminde, Denmark), rapeseed oil (Apetit Kasviöljy Oy, Kantvik, Finland), potato starch (Finnamyl Oy, Kokemäki, Finland), rice flour (Virtasalmen Viljatuote Oy, Virtasalmi, Finland), poppy seeds (Meira Oy, Helsinki, Finland), sunflower and sesame seeds (Mauste-Sallinen Oy, Naantali, Finland), and dry herb mix (Mauste-Sallinen Oy, Naantali, Finland).

The selection of ingredients also enabled increased content of dietary fibre and protein in the customized snacks. If customized by extra fibre or protein, the snack was high in dietary fibre or high in protein based on nutrition claims (European Parliament and Council, 2006). Adding extra fibre or protein could increase the image of healthiness. For customization (the first version of function), there were three sweet and one savory basic recipe options (Fig. 1), but only the chocolate-tasting one was available for production in practice. For personalization, there were only savory options: three oat-based snacks with or without seeds and/or herbs, three chickpea-based snacks with or without seeds and/or herbs, and three chickpea and oat -based snacks with or without seeds and/or herbs. The snacks for personalization were designed to be all low in sugar, high in dietary fibre, and either high in protein or source of protein, based on nutrition claim regulation (European Parliament and Council, 2006). Nutritional composition of the snack options available for production is presented in Table 1. The final weight of a portion of the baked product was 70 g.

2.2. User studies: customized and personalized snack production

The aims of the user studies were to understand consumers' attitudes and perceptions about added value of customization and personalization of snacks and about usability of the prototype snack vending machine. We also wanted to achieve information for the further development of the snack machine, in terms of its features, customization and personalization options, and functionality of the personalization platform, as well as machine's ability to prepare palatable products. Questionnaires were applied to measure respondents' experiences about the usability of the machine, their preferences of and interest towards different customization and personalization options as well as their perceptions of added value of the snacks and using this kind of a snack machine. For clarity of the two separate user studies, the methods are directly followed by results and described in detail in the Section 3. User studies and results.

2.3. Data analyses

The user studies apply basic descriptive analyses, and the results are presented as percentages and means ± standard deviations (SD). In both user studies, a general attitude variable towards the machine was calculated as means of four semantic differentials, and in the user study 1, a general intention to use the machine in the future was calculated as means of three items of likelihood of the usage (see Section 3.1.2 Measures). For statistical comparisons in both user studies, non-parametric one sample Wilcoxon test, instead of one-sample *t*-test, was chosen because the data consisted of ordinal responses on a 5-point Likert scale and this test does not assume that the data are normally distributed. The one sample Wilcoxon test was used to assess whether the mean scores significantly deviated from the neutral opinion (that is from 3 on the scale of 1–5). After the analyses, corresponding effect sizes were calculated through the following formula $r = \frac{z}{\sqrt{n}}$. The effect sizes were interpreted following Cohen (1992) recommendation 0.10 for small, 0.30 medium, and 0.50 or above for large effects. All quantitative data were analyzed using the IBM SPSS Statistics software for Windows, version 28.0 (IBM corp, US). Results were regarded as statistically significant when the p-value was < 0.05.

3. User studies and results

3.1. User study 1 – customized snack production

3.1.1. Sample characteristics and procedure

In November 2019, a convenience sampling procedure was used for recruiting voluntary adult by-passers at a mall corridor in Espoo, Finland, where the snack machine for customized snack production was located for four days. In recruitment speech, potential participants were informed about the purpose of the study as well as about what was expected from them (to test the machine by selecting and ordering a snack,

Table 1
Nutritional composition of sweet and savory snacks per 100 g of product. Only snack options available for production and with relevance to macronutrient composition are shown.

	Recipes	Fat (g/100 g)	Protein (g/100 g)	Carbohydrates (g/100 g)	of which sugars (g/100 g)	Dietary fiber (g/100 g)	Energy (kcal/100 g)	Energy from protein (%)
Sweet	Chocolate*	13.3	10.0	28.6	15.4	2.0	278.1	14.4
	Chocolate + fiber	11.4	8.6	24.6	13.2	10.0	255.3	13.5
	Chocolate + protein	12.1	14.3	26.1	14.0	1.8	273.9	20.9
	Chocolate + protein and fiber	10.2	13.0	21.9	11.8	10.0	251.3	20.7
Savory	Oat	11.6	9.4	15.5	0.5	10.4	224.6	16.7
	Chickpea	6.6	10.0	13.7	0.8	10.3	174.5	22.9
	Oat-chickpea	11.0	9.7	14.0	0.6	10.4	214.8	18.0
	Oat-seed	12.9	9.8	15.4	0.6	10.4	237.4	16.4
	Chickpea-seed	8.1	10.3	13.6	0.8	10.3	188.9	21.9
	Oat-chickpea-seed	12.4	10.0	13.9	0.7	10.4	227.9	17.6

* For customization, only the sweet chocolate recipe was utilized in practice during the user study 1. If additional protein and/or dietary fiber was selected, the nutritional information was presented on the user interface.

evaluate usability of the machine as well as rate sensory characteristics of the snack and answer a short questionnaire anonymously). They were also informed that they can discontinue the testing any time without giving a reason. The questionnaire did not include any questions allowing identification of the respondent. The snacks produced were safe for consumption and respondents' potential allergies to any ingredients in the cake-in-a-cup were checked. Besides the minimum age of 18 years, and no allergies or other reasons for not being able to eat the product, no additional screening criteria were applied. The participants were compensated for their participation with a movie ticket. Data collection, handling and processing followed the ethical principles of research with human participants in the human sciences in Finland (TENK, 2019). As no personal information was gathered, informed consent was gained, and there were no other reasons for requiring ethical review, no application for ethical review was submitted to the ethical committee.

In total, 81 consumers participated in the study. Based on answers in the study questionnaire, a bit over half of them reported to be men. The age group of 18–30 y was dominant (67 %), however other age groups were also represented (21 % of 31–50 y, and 12.5 % of 51–70 y). None of the participants followed any special diet because of allergies or diseases. Half of the participants (48 %) were in the habit of eating snacks every day, one third (33 %) ate snacks a few days a week, and 16 % once or twice a week. Quite many participants (44 %) reported purchasing snacks often from a shop or a kiosk while 15 % often took snacks from home and 15 % purchased them from a canteen or restaurant. Purchasing snacks from a vending machine was not common among the participants since 49 % never and 38 % seldom did so.

The participants were asked to use the snack machine to order a snack. For the participants, the snacks were simply called muffins although in this article we call them 'cakes-in-a-cup'. Choices of snacks and extra options were made according to the decision tree described in Fig. 1. After all choices were made, the participants saw a graph of nutritional contents of the cake-in-a-cup in terms of its' "energy from protein", "fiber g/100 g", "carbohydrates g/100 g" and "fat g/100 g". The information was presented per 100 g as it is customary to consumers and based on EU Food information regulation (European Parliament and Council., 2011).

After finishing the order, the participants waited for four minutes the machine to bake the cake, which came out of the machine in a carton cup. Regardless of their choices, this prototype version of the snack machine prepared only a chocolate cake-in-a-cup due to technological challenges faced during the study. The participants were informed about this only after the product was baked. After getting the prepared cake-in-a-cup, the participants were asked to taste the product, and to fill in an anonymous online questionnaire about the customization, usability and added value of the machine, and their attitudes with laptop provided at the testing site.

3.1.2. Measures

The first section of the questionnaire collected information on participants' background in terms of basic demographics (sex, age group). It also included a few questions about eating habits such as frequency of eating snacks and about frequency and different ways of obtaining snacks.

Participants' attitudes towards the machine (assuming it would be available for their use) were measured with 4 semantic differentials on 5-point scales (1 – 5): The question read: "To me the machine would be…" with the following items in the scale: "bad thing - good thing", "useless – useful", "unnecessary – needed", "annoying – pleasing".

Information about which snack option the participants had chosen (snack choice) and whether and which customization choice they had made i.e. which extra ingredients (fiber and protein; dairy, pea, or oat protein and oat, wheat or corn fiber) they had selected was also collected as part of the questionnaire. Respondents' perceived desirability of the customization options as offered by the machine were measured with scales ranging from 1 = undesirable to 5 = desirable. Expected future use of customization options was measured by asking participants how often they would utilize the customization options of extra protein and fiber, as well as some other potential future features such as adjusting amount of sugar or content of fat or adding extra berries, with scales ranging from 1 to 5, where 1 = never, 2 = rarely, 3 = occasionally, 4 = often, and 5 = always.

The perceived usability of the snack machine was measured by asking the participants to rate functionality of the machine, ease of use, pleasantness of use, speed of use, clarity and understandability of the menus and information provided by the UI as well as amount of information provided and appearance of the UI. For these measured, a five-point scale ranging from 1 = poor to 5 = good was applied. Respondents' perceptions of added value from this kind of a snack machine when compared to their current practices of getting their snacks was measured with two sets of statements. The first one addressed the snack: *"I believe my snacks would be… healthier / more natural / fresher / more ecological / more delicious / more satiating / meeting better my desires and needs"*. The second one addressed the machine with statements: *"I believe that by using this kind of a machine… it would be easier for me to acquire my snacks / I would save time / I could maintain vitality / my snacks would be of better quality / my snacks would be healthier / I could keep up better / weight maintenance would be easier / I would have better control on the type of snacks I eat*". The applied rating scale ranged from 1 = completely disagree to 5 = completely agree.

Intention to use the machine in the future (provided it would be available and accessible) was measured with three items asking respondents to rate their likelihood to 1) use the machine regularly, 2) use it at least occasionally, 3) use it in case it would be improved according to their desires. Applied rating scale ranged from 1 = "It is likely I would not use" to 5 = "it is likely I would use".

Perceived need for the machine in different locations was measured by asking the participants to rate nine different locations in terms of how useful / necessary the existence of the machine in these places would be for them on 5-point scales ranging from 1 = not at all necessary to 5 = very necessary).

To assess if the machine was able to produce a snack of good quality, the participants were asked to rate the sensory and other quality evaluations (taste, texture, appearance, healthfulness, freshness, and pleasantness) of the chocolate cake-in-a-cup after tasting it. The applied rating scale ranged from 1 =very bad to 5 =very good.

3.1.3. Results

Participants' overall attitude towards the customizing snack machine was positive (mean 3.5 ± 0.8; $p < 0.001$, $r = 0.49$, as compared to the neutral value of 3). As for the individual attitude items, most of the participants (75 %) rated the snack machine as pleasing rather than annoying (scores above the neutral score 3 in the scale of 1–5), and 61 % rated it would be a good thing. However, only 48 % thought it would be useful, and just 28 % felt it would be needed. The overall intention to use the machine was on the positive side (mean 3.2 ± 0.8, $p < 0.05$, $r = 0.24$). In more detail, 14 % of the participants were likely to use the snack machine regularly, 61 % at least occasionally, and 53 % in the case if it were improved.

Over half of the participants (62 %) utilized customization by making extra choices of either fiber or protein or both. From all the participants, 43 % chose extra fiber and 48 % chose extra protein for their snack. Oat was the most often selected fiber source by 71 % of those who made the extra fiber choice (n = 35). Oat and dairy proteins were chosen as protein sources by 49 % and 41 % of the participants, respectively. The respondents valued possibilities to customize the snack by selecting extra fiber and protein (means of item "undesirable – desirable" 3.5 ± 1.5 for extra fiber; $p < 0.01$, $r = 0.32$, 3.5 ± 1.4 for extra protein; $p < 0.01$, $r = 0.33$).

Close to half of participants expressed they would always or often choose extra fiber (45 %) or extra protein (48 %), if this type of snack machine was available. However, participants selected other hypothetical customization options as well. Adjustment of fat content (49 %), amount of sugar (66 %), and especially addition of extra berries (69 %) were popular options, which these participants would choose either often or always.

Participants' perception of added value of snacks from this kind of snack machine if universally available for them, and when compared to their current way of acquiring snacks, varied between the individual statements (Fig. 4A). 81 % of the participants agreed their snacks would be fresher (with mean of the full sample 4.2 ± 0.9; $p < 0.001$, r = 0.76) and about half (48 %) agreed that they would be more delicious (3.4 ± 1.1; $p < 0.05$, r = 0.28). When evaluating if the snacks would be healthier, the participants disagreed with this statement (2.7 ± 1.0, $p < 0.01$, r = -0.30). Most participants did not agree or disagree with the other statements. For example, 44 % of the participants did not agree or disagree that the snacks would be ecologically more sustainable, reflecting the average neutral opinion towards sustainability of the snacks (3.1 ± 0.9).

Participants' perception of added value of the snack machine, when compared to their current way of acquiring snacks, also varied between the separate statements (Fig. 4B). From the participants, 65 % agreed acquiring snacks would be easier (3.7 ± 1.0, $p < 0.001$, r = 0.53), and 41 % agreed they could better maintain their vitality (3.2 ± 0.9; $p < 0.05$, r = 0.23). However, 54 % disagreed with the statement "weight management would be easier" (2.4 ± 1.2; $p < 0.001$, r = -0.43) and 46 % disagreed that their snacks would be healthier (2.7 ± 1.1; $p < 0.001$. r = -0.26) when acquired from this kind of machine. The participants did not agree or disagree with the other statements.

The usability features of the snack machine were rated as good on average (Fig. 5). Most of the participants regarded the machine as easy to use (84 %), pleasant to use (75 %), and as clear and understandable (70 %), based on the ratings above the neutral score of 3 in the scale of 1–5.

Regarding the perceived need for this type of machine in various locations, 68 % of the participants reported that this type of snack machine would be needed at a workplace or study area, while about a half (48 %) reported it would be needed at a sports facility. However, many participants (59 %) did not see a need for the machine at a shopping center.

The participants also evaluated the sensory quality of the snack and rated the chocolate cake-in-a-cup as quite good. It was evaluated to be very fresh (4.5 ± 0.6; $p < 0.001$, r = 0.85), somewhat tasty (3.6 ± 0.7; $p < 0.001$, r = 0.69) and to have quite good texture (3.4 ± 1.0; $p < 0.001$, r = 0.37). Appearance (3.1 ± 0.9), and healthiness (2.9 ± 0.9) of the cake-in-a-cup received neutral evaluations. The overall pleasantness was evaluated to be quite good (3.5 ± 0.7; $p < 0.001$, r = 0.59).

3.2. User study 2 – personalized snack production

3.2.1. Study design and sample

In December 2023, the snack machine prototype with further developed UI and with integration to the personalization platform was placed in a high school recreation room in Espoo, Finland, for four working days of testing. The location was chosen based on results from user study 1, where many participants had indicated that the snack machine would be useful in a workplace or study area.

Voluntary participants without allergies to oats or eggs or any other ingredient in the snack products were recruited from the employees of the high school with the help of announcements distributed on noticeboards and on the intranet. Altogether 23 participants, of which 52 % reported being females, participated in the testing. They were on average 40 ± 14 years of age with mainly a master's or higher degree (74 %). The rest, 26 %, had a vocational education. Most of the participants (70 %) reported eating snacks at their workplace. Of those who eat snacks at workplace, 52 % often or every now and then bring the snacks from home. Whereas 43 % of the participants indicated that they often or every now and then purchase their snacks from a shop, and 30 % from a canteen or restaurant. Acquiring snacks for the workplace from a vending machine was not common, as 60 % never and 40 % every now and then purchased a snack from a vending machine.

Participants were informed that by using their personal identification code for logging into the personalization platform they were providing their informed consent to participate in the study. They were informed they could withdraw from the study at any time after logging in, without needing to provide a reason. The study design was performed in compliance with relevant laws and institutional guidelines, also following EU's general data protection regulation. The participants were informed that their personal data (contact information) collected in the recruitment phase is pseudonymized for the duration of the snack machine testing and anonymized after finishing all the tests. The personalization platform did not collect or store participants' contact information. Thus, the personalization data at the platform was temporarily protected by pseudonymization and permanently protected by anonymization. The ethical approval was applied and gained from the ethical committee of VTT Technical Research Centre of Finland Ltd (131543, approval date 22.9.2023).

3.2.2. Procedure and measures

Before testing the snack machine at the workplace, the participants needed to log in to the personalization platform to enter their data about the dietary requirements and preferences (as described in 2.1.1). The

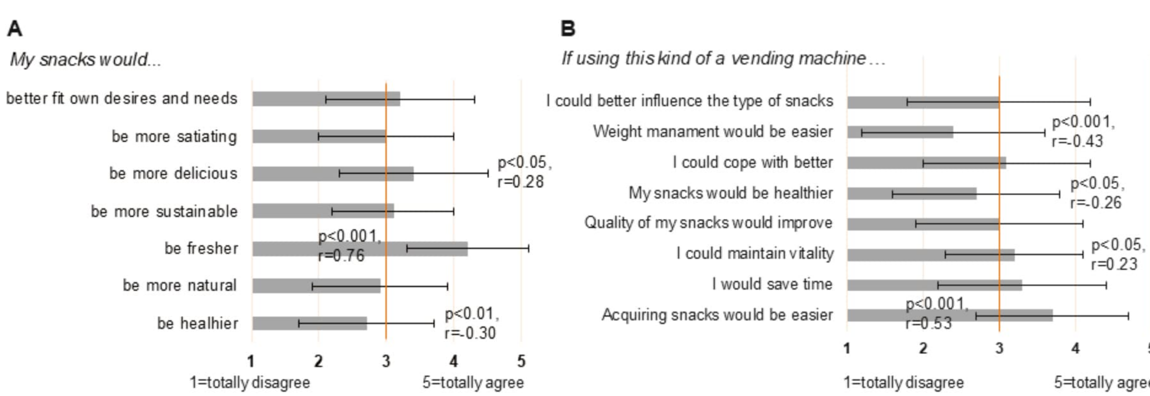

Fig. 4. Participants' perceptions of added value. Participants' (n = 79–80) agreement with the presented statements about the snacks from the snack machine (A) and the machine itself (B) when compared to their current way of acquiring snacks, assuming the machine was universally available to them. Bars show the means of agreement with standard deviations on the 1–5 scale in which the neutral value is 3. p-values are from the one-sample Wilcoxon test in comparison to the neutral value, presented with r-values showing the effect size.

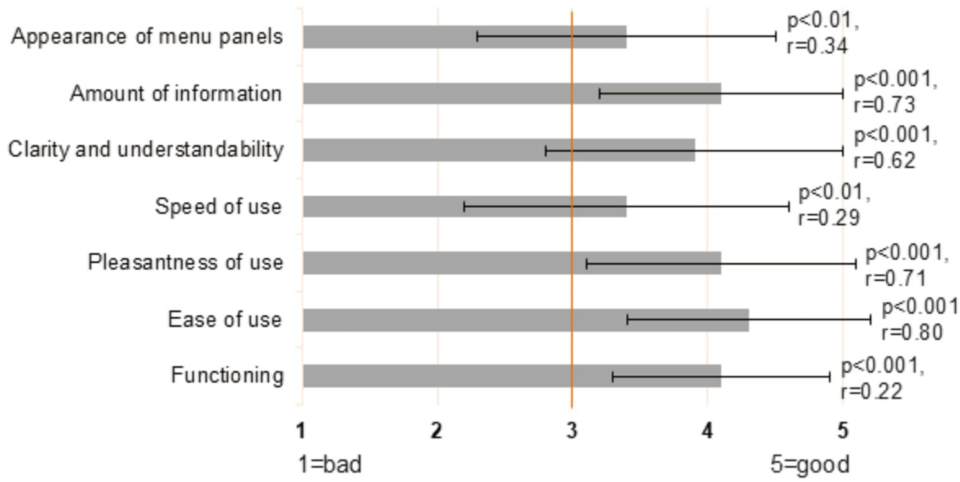

Fig. 5. Usability of the snack machine evaluated by participants (n = 77–79). Bars show the mean of estimations with standard deviations on the 1–5 scale in which the neutral value is 3. p-values are from the one-sample Wilcoxon test in comparison to the neutral value, presented with r-values showing the effect size.

actual testing sessions were scheduled in advance for each participant. Upon entering the testing session, the participants first answered background questions on a tablet provided to them. The questions were about basic demographics (such as sex, age, educational background) as well as eating habits including how they obtain and consume snacks at the workplace. Usability of the personalization platform was evaluated by assessing the process of entering the information on a scale of 1–5 (laborious – easy/effortless, slow – fast, annoying – pleasing, complicated – simple, unclear – clear).

Then, the participants used the snack machine to order a savory muffin. Before confirming the order of the chosen product, the UI presented the ingredients and allergens, and amount of energy (kcal), protein (g), fat (g), saturated fat (g), carbohydrates (g), sugars (g), and dietary fiber (g) per portion of the ordered product (unlike in the user study 1). While waiting for the snack to be baked, the participants completed the questionnaire concerning the personalization, usability and added value of, and their attitudes towards, the machine. Attitudes towards the machine producing fresh products were measured similarly as in the user study 1. Participants were asked whether they chose the recommended snack option, based on the personalization parameters entered in the platform, or made their own choice (with options *yes, no, cannot say*). Their attitude towards the snack recommendation function was measured by asking whether the snack recommendation was suitable, useful, and pleasing by using assessment of three semantic differential items in a scale of 1–5 (unsuitable – suitable, useless – useful, not pleasing – pleasing). Participants were asked what from the following three options would be the best to make the product choice: 1) personalized recommendation without own final choice, 2) personalized recommendation with own final choice, 3) no personalized recommendation but own choice. Usability of the snack machine was measured similarly as in the user study 1, but evaluation of the appearance of the UI was excluded to shorten the questionnaire and to enhance focus on other features.

In this study, we also wanted to understand how important the snack features enabled by the snack machine were perceived. The participants were asked how important (in a scale of 1–5; 1 =not important at all and 5 =very important) they perceive a snack to be fresh, warm, high in fiber, high in protein, have good fat quality, and a small carbon footprint. Also, we explored whether the participants perceived added value from using a snack machine producing fresh snacks in comparison to their current habits in acquiring snacks. To do this, the participants were prompted to express their agreement with a similar set of statements as in the user study 1. The question read: *"I believe that by using this kind of a machine…"* with following items: *it would be easier for me to acquire my snacks / I would save time / I could maintain vitality / my snacks would be of better quality / my snacks would be healthier / I could cope with better / weight maintenance would be easier / I would have better control on the type of snacks I eat"*. The applied rating scale ranged from 1 = completely disagree to 5 = completely agree. Finally, the participants were asked to taste the ordered product and indicate their liking to understand the machine's capability to produce sufficient quality snacks. The same procedure for rating sensory and other quality as described in study 1 was applied.

3.2.3. Results

The usability of the personalization platform integrated with the snack machine was rated positively on average (Fig. 6). Most of the participants (on average 85 %), based on the scoring above the neutral 3 on the 1–5 scale, evaluated it was easy, fast, simple, and clear to enter the required data onto the platform. Almost half of the participants (48 %) also thought it was pleasing to enter the data, while 35 % gave a neutral opinion about the pleasantness of data entering (score 3).

Almost all the participants had positive general attitude towards the snack machine producing fresh products, in comparison to the value of 3 for neutral opinion (mean of the four attitude variables 4.1 ± 0.6; $p < 0.001$, $r = 0.84$). As for the individual attitude variables, most of the participants (87 %) perceived the snack machine to be a good thing (scores above the neutral score of 3 in the scale of 1–5), 83 % thought it would be pleasing, 78 % rated it would be useful, and 57 % thought it would be needed.

Almost every participant (91 %) chose the cake-in-a-cup that was recommended to them by the machine. Only two participants did not follow the recommendation but made their own choice when ordering the product. Among the participants, when compared against the neutral opinion value of 3, the product recommendation was perceived suitable (4.2 ± 0.8; $p < 0.001$, $r = 0.81$), useful (4.4 ± 0.8; $p < 0.001$, $r = 0.83$) and pleasing (4.0 ± 1.1; $p < 0.01$, $r = 0.66$). With exception of one participant, all (96 %) stated they would like this kind of a snack machine to recommend them suitable options based on their own data, but they would like to have the freedom of choice to make the final choice. Only one participant preferred recommendation without own choice, and nobody preferred the option without any recommendation but fully making their own product choice.

The participants were prompted with questions concerning the importance of snack features enabled by the snack machine. In general, all the aspects, except snack warmness, were perceived important, deviating statistically significantly from the neutral (3) rating (Fig. 7A). Participants' perception of added value of the snack machine, if it would be at their workplace, and when compared to their current way of acquiring snacks, was also positive (Fig. 7B). Participants, for example,

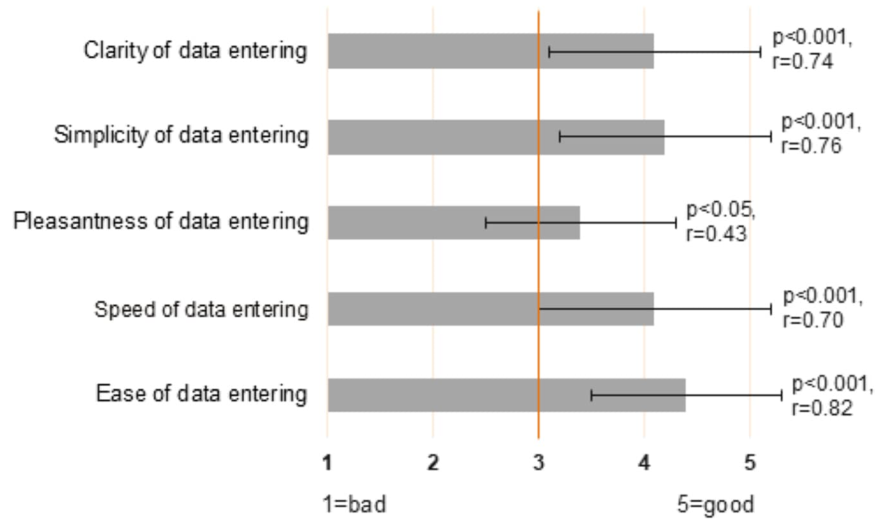

Fig. 6. Usability of the personalization platform evaluated by participants (n = 23) as features of data entering. Bars show the mean of estimations with standard deviation on the 1–5 scale in which the neutral value is 3. p-values are from the one-sample Wilcoxon test in comparison to the neutral value, presented with r-values showing the effect size.

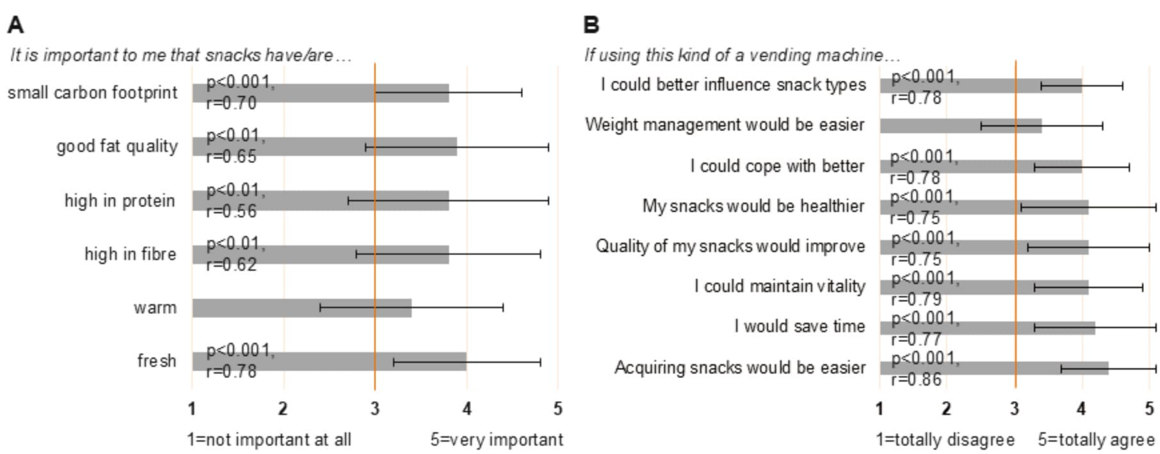

Fig. 7. Means of perceived importance of the listed snack features (A) and means of agreement with the statements related to using the snack machine, if available at their workplace, and as compared to the respondents' current way of acquiring snacks (B), n = 23. Bars show the means with standard deviations on the 1–5 scale in which the neutral value is 3. p-values are from the one-sample Wilcoxon test in comparison to the neutral value, presented with r-values showing the effect size.

perceived that by using this kind of a vending machine they would be able to get their snacks easier, save time, and get healthier snacks. Thus, this vending machine would also help them to keep up their energy levels throughout the day. The only statement that was rated as neutral on average was "weight management would be easier".

All the usability features of the snack machine (functioning, ease of use, pleasantness and speed of use, clarity and understandability, and amount of information provided) were evaluated positively on average (Fig. 8). The participants tasted the cake-in-a-cup of their choice and evaluated the overall sensory pleasantness to be somewhat good (3.4 $\pm$ 0.7; $p < 0.05$, $r = 0.52$). The product was also rated as fresh (4.4 $\pm$ 0.7; $p < 0.001$, $r = 0.84$), healthy (4.3 $\pm$ 0.6; $p < 0.001$, $r = 0.89$) and the texture as relatively good (3.7 $\pm$ 0.6; $p < 0.001$, $r = 0.75$). The taste (3.2 $\pm$ 0.6) and appearance (3.0 $\pm$ 0.6) were rated as average.

4. Discussion

In this project, a prototype snack machine with two separate functional versions – food customization and food personalization – was constructed to offer freshly baked snacks on demand. The snack machine providing consumers either the possibility for customization or personalization was tested with voluntary participants to understand their attitudes towards the machine and to demonstrate if the machine and its functions are usable and if they create added value for users. In the first user study, the snack machine allowed consumers to customize the snack by selecting extra fiber or protein. In the second user study, the machine offered snack recommendations based on data the consumers had previously provided via a personalization platform about their dietary and food preferences. User feedback was collected for both versions separately.

The developed snack machine prototype with both versions of function was generally well-received with positive attitudes by participants of the user studies. In the second study (concerning the machine with the personalization function, n = 23), a higher percentage of participants (57 %) indicated the snack machine would be needed compared to the first study (28 %) on the machine with the customization function (n = 81). The perceived lack of usefulness of the customization was also reflected in the responses, with only 14 % of participants indicating they would like to use the machine regularly if it were available. However, the study design and the small convenience samples do not warrant conclusions about the superiority of these machine versions. These results are suggestive and need to be confirmed in

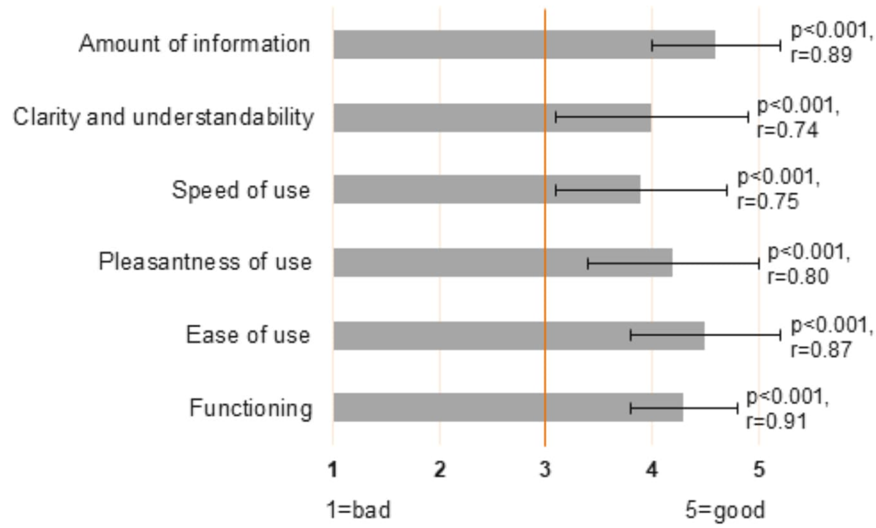

Fig. 8. Usability of the snack machine evaluated by participants (n = 23). Bars show the mean of estimations with standard deviations on the 1–5 scale in which the neutral value is 3. p-values are from the one-sample Wilcoxon test in comparison to the neutral value, presented with r-values showing the effect size.

future studies.

Customization was popular in the test situation, as over half of the participants in the first user study chose either extra fiber or protein in their snacks. In addition, nearly half of the respondents indicated they would always or often choose extra fiber (46 %) or protein (49 %) if ordering snacks from the machine. The participants showed even more interest, for example, in adjusting the sugar content (66 %) and customizing their snacks with added berries (69 %).

The snack machine with the personalization function was highly valued by participants. In the test situation, almost every participant chose the product recommended by the machine, which was based on the data they had previously provided. They were also satisfied with the product recommendation. These results hint that consumers may find personalization function as more interesting than customization feature in a snack machine. However, as these results are based on relatively small studies the interpretation warrants caution. For example, self-selection bias cannot be ruled out. Possibly consumers who were initially interested in personalization were more likely to take part in the study. On the other hand, there are many reasons why consumers indeed may prefer personalization over customization. Compared to the possibility of tailoring a few ingredients, personalization allows consumers more influence on the snack characteristics. This can be even taken further with AI integration into the personalizing machine. AI-driven personalization has been shown to significantly enhance consumers' purchase intentions by increasing the perceived relevance and value of food choices (Wang et al., 2025). This suggests that integrating AI-based personalization into vending systems could meaningfully improve the snack selection process by aligning recommendations with individual health goals and preferences.

In the first user study, participants agreed that snacks ordered from the customizing snack machine would be able to provide them fresher snacks compared to the snacks they currently consume. Most participants in the second user study emphasized the importance of snack freshness, and the cake-in-a-cup they tasted was rated as significantly fresh. Therefore, one clear benefit of the developed snack machine is its ability to provide freshly made bakery products from scratch.

However, a fresh snack is not necessarily a healthy one. We had recognized that customization in vending machines can be used to offer products with healthier features. Related to nutritional content, the healthy features were designed based on nutrition claims for dietary fibre and protein, and also for sugar in the user study 2. However, participants in the first user study significantly disagreed that snacks from the customizing machine would be healthier than those they currently consume. This suggests that participants did not believe that adding fiber or protein would make the snacks provided by the machine healthier compared to their current snack choices. Nutritional information provided by the snack machine's UI unlikely affected participants' perception of snack healthiness as they were not able to compare simultaneously the nutrient content information with that of their current snacks.

It is important to note that, regardless of whether the participants selected a sweet or savory snack in user study 1, every participant received a chocolate cake-in-a-cup prepared by the machine. Chocolate is known to be high in calories and calories are often a key factor in how consumers assess a product's healthfulness (Campbell & Warren, 2015). This has most likely influenced participants' low ratings of snack healthiness in the customization study. The participants may have judged the healthfulness of the snack based solely on the chocolate version they received and tasted. This could also explain why participants disagreed with the statement that using the snack machine would aid in weight management. It has been shown that consumers often are not able to assess the impact of their customization choices on the food's energy content (Besharat et al., 2021). Therefore, the product name ("chocolate cake-in-a-cup") or mentioned ingredients likely influenced participants' image of the snack's healthfulness. In the second user study, where all snack options were savory, participants did rate the cake-in-a-cup they received and tasted as healthy.

Although participants in both user studies were not regular users of vending machines for snacks, most rated the usability of the newly tested snack machine positively. Every feature of the usability was rated as good, with significant deviations from a neutral opinion. Since convenience is a key factor in purchasing snacks from vending machines (Caruso et al., 2014), positive feedback about usability encourages further development of the snack machine prototype for commercial purposes. In addition, the developed snack machine proved functional in terms of snack preparation. In both studies, the machine successfully prepared freshly-baked cakes-in-a-cup, which were rated positively for their sensory properties such as taste, texture, and overall pleasantness, or received neutral ratings for taste and appearance. Furthermore, the specialty of these machines – the ability of providing freshly-baked snacks – was clearly valued by the test users. Given that the functionality of the personalization platform was also rated as good, there is a practical opportunity to integrate personalization into the vending machine industry. Future studies should focus on improving the user experience of pleasant data entering onto the personalization platform, as this aspect was not rated as highly as the other functionality features of the platform.

4.1. Market feasibility of customizing and personalizing snack machines

This paper presented the development and user studies of two on-demand snack machines, one aimed for customizing and the other for personalizing baked snacks for consumers. The results of the studies bear some practical implications, which are observed from market feasibility perspective. Starting with the market demand, the results indicate that, overall on attitude level, participants accepted the idea of customizing and personalizing snack machines. This is naturally the first and foremost criterion for market feasibility of snack machines. However, when the results are observed in more detail and especially from the market demand perspective, 28 % of those who tested the customizing machine (user study 1) and 57 % of those who evaluated the personalizing machine felt that such machines are needed. Considering that controlled experiments often come with biases (e.g. participants might overemphasize the views they consider the study personnel are looking after), these numbers are not too encouraging, especially in the case of customizing snack machine. At the moment, there are neither specific knowledge on potential target consumer segments nor their sizes. User study 1 indicated that e.g. workplaces might be suitable locations for customizing snack machines, but that is still only a very rough description of a potential target group. Naturally, workplaces differ and consumers within the workplaces vary in their attitudes and behaviors concerning snack consumption. Thus, larger studies are required to gain valid estimations on market demand.

Another aspect of market feasibility covers the competitors. From that perspective, customizing or personalizing on-demand snack machines do not face fierce direct competition as reviewed in the Introduction. When competitors are considered more widely, then for example cafeterias, bakeries, kiosks, and retailers serving fresh snacks (e.g. sandwiches, fruits) come into play. The current study did not consider the competition aspect directly. However, some of the results can provide understanding on how the customizing or personalizing snack machines are viewed against participants' current habits to acquire snacks. One of the benefits the participants saw in both machines was the easiness to acquire snacks in comparison to their current practices. With regards to the personalizing machines, user study 2 participants considered several other improvements in their snack acquiring as well, including healthier and higher quality snacks (in user study 1 no other benefits beyond easiness emerged). These results imply that especially personalizing machines might have potential to stand out from the competitors in a positive sense. However, the study design does not allow understanding on what type of snack acquiring practices (e.g. from where, what type of snack) the participants were thinking while making comparisons against snack machines. Thus, it remains unknown how snack machines would perform against specific competitors.

One element of market feasibility refers to the marketing strategy dealing with location of the machines, pricing of the snacks, and promotion content. User study 1 tackled the location of the customizing snack machine. The participants considered workplaces as the most feasible location, also sports facilities were perceived suitable by many. The common nominator between these two is the isolation from other potential places to acquire snacks. This result might indicate a need for snack supply in these locations, however, too far-fetched conclusions should be avoided due to the nature of this study. When it comes to pricing the products, the issue is complex. The pricing is heavily dependent on the volumes. As the machines operate with fresh ingredients, also the shelf life of the ingredients plays its own role. The less demand, the more potential financial losses emerge from food waste. On the other hand, the more demand, the more often the machines require filling of the ingredients, which contributes to the costs. Overall, this study does not provide much on the pricing topic, thus the issue remains for future studies. The situation is slightly different with the promotional content (i.e. explicit value proposition to consumers). User study 1 revealed that, in a first place, the participants perceived that customizing machine can produce fresher and more delicious snacks than what they typically consume. Indeed, the sensory evaluation results were aligned with these preliminary perceptions as the participants rated the product relatively tasty and very fresh. In user study 2, similar comparison between the currently consumed snacks and the one the machine produced was not made. However, the sensory evaluation results were again showing that the products were considered somewhat tasty and very fresh. One of the main ideas behind both machines is the capability to produce healthy on-demand baked snacks. The results concerning this are mixed. In user study 1, the product was not considered healthy compared to the current snacks the participants consume. In sensory evaluation, the healthiness of the product was questioned as well. In user study 2, the snacks were considered very healthy after tasting. The deviation between studies is probably because in the first study the machine baked only chocolate cake-in-a-cup, which naturally conflicts with the healthiness by nature. Therefore, healthiness can be also considered as one value for consumers, at least in the case of personalizing machines. Taken together, the results of this study suggest that consumers could be approached through three core promotional contents: fresh, tasty, and healthy snacks. These three could also be enriched with convenience in acquiring snacks (see earlier discussion).

4.2. Limitations and implications for further research

This study has limitations. First, the sample sizes in both user studies are modest, which have effects on generalizability of the results. This is because the overall purpose of these studies was to investigate consumers' initial attitudes towards the machines and their usability to gather information for further development. Thus, because of the small convenience samples, the results about users' opinions and attitudes cannot be generalized to a broader population. User study 1 relied on convenience sampling, therefore, by its best, it represents the clientele of the shopping mall in which the study was performed. User study 2 took place among high school personnel. Despite the significant share of the personnel attended the study, it is still a small snapshot and does not provide much means for generalizing the results over wider populations. While the choice of the test location (a workplace) for the snack machine was based on feedback from the first study, an updated version of the machine with personalizing function should be tested also in other types of locations (e.g. schools, public transport hubs, workplaces) and larger scale field studies in real-world environments would be useful to gain ecological validity for the results. Such endeavors would contribute to evaluating the commercial feasibility of snack machines by understanding how consumers in different use situations and varying target groups would respond to the opportunity to either customize or personalize snacks on demand.

Second, no special attention was paid to the personal characteristics when recruiting voluntary participants for the user studies. Recent findings suggest that consumers are more likely to prefer customized food when they have expertise on the topic (Li et al., 2022). Additionally, self-image plays a role, as those who view themselves as unhealthy eaters are more likely to perceive their food as unhealthy compared to those who consider themselves healthy eaters (Klesse et al., 2019). Furthermore, the choice of healthy products is influenced by individual characteristics such as health consciousness (Arroyo et al., 2020). These are examples of how consumers' psychographic characteristics, their values, preferences, and prior experience and familiarity with the issue, may have considerable influence on their attitudes, preferences, and behavior (Arroyo et al., 2020). Therefore, as the studies reported here had no control on, for example, dietary habits or psychographics, it cannot be ruled out that the samples have been biased with consequent influence on the results. Thus, careful selection of the target group is important especially for successful consumer-led customization of healthy food.

Third, the first version of the machine could only prepare chocolate cakes-in-a-cup, regardless of users' choice. It was obvious that the unhealthy image of chocolate bakery confounded the results regarding particularly healthiness ratings. In future, this type of snack machine should offer healthy and fresh snacks displayed in a way that elicits clear associations with healthiness in consumers' minds. When communicating health-related product information to consumers, the product name and recognizable healthy ingredients (such as berries and oat) may be more impactful than detailed macronutrient information (e.g. protein and dietary fiber). Although food customization raised interest among participants, a carefully segmented consumer group should be identified for this type of vending machines. A larger consumer study could explore their psychographic variables, including health consciousness, interest and knowledge related to food and health, as well as their snacking habits. For the snacks prepared and baked by the machine, improving their appearance and taste is essential to encourage regular use of the machine. Finally, the results of this study are specific to the tested prototype snack machine. The participants recognized that they tested and evaluated an unfinished version of a snack machine, which may have influenced their assessments. Further research is needed to evaluate the usability and user responses of the finalized version of the snack machine.

Finally, participants in user study 2 were prompted with several items regarding the importance of snack properties (e.g. good fat quality, high in protein). However, the level of sugar was ignored although it has been found important once consumers evaluate the healthiness and palatability of food products (Prada et al., 2021). This matter was indirectly touched upon in user study 1 in which more than half of the participants considered that they would adjust the snack sugar level often or always. However, user study 1 did not take stand on whether the participants would increase or decrease the sugar amount. Considering the impact of sugar level on consumers' attitudes towards food products, this could be considered as limitation for user study 2 and could be taken into consideration in forthcoming studies.

5. Conclusions

We developed a new type of snack machine that produces fresh bakery snack products on demand and offers consumers to customize snacks or receive personalized snack recommendations based on their data. Participants in our user studies tested the snack machine producing fresh products either with functions of customization or personalization. Overall, the participants, who were very occasional users of vending machines, viewed the usability and added value of the snack machine positively. Food customization options, such as adding extra protein or extra fiber, were popular during testing. However, it was unclear whether these specific customization features would be worth further development. Instead, the personalization function clearly provided added value. Participants preferred the products recommended to them, were satisfied with these recommendations, and liked the snack machine to recommend suitable options if the machine was commonly available. The results encourage further development of vending machines that offer freshly baked snacks with possibility for personalisation. As the small convenience samples limit generalizability of the findings, more systematic and larger-scale consumer studies are needed to confirm the conclusions, to refine target groups, assess market feasibility, and guide technological improvements.

CRediT authorship contribution statement

Anne Arvola: Writing – original draft, Validation, Methodology, Investigation, Conceptualization. **Adil Umer:** Writing – original draft, Visualization, Validation, Software, Data curation. **Alex Calton:** Writing – original draft, Visualization, Methodology, Investigation. **Pekka Kilpeläinen:** Writing – original draft, Software, Methodology. **Saara Vanhatalo:** Writing – review & editing, Methodology, Conceptualization. **Nesli Sozer:** Writing – review & editing, Supervision, Resources, Funding acquisition, Conceptualization. **Kyösti Pennanen:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization. **Jenni Lappi:** Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

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.

Acknowledgements

This work was supported by Business Finland [grant number 6666/31/2021] and VTT's government grant [no. 121739].

Eero Päiväkumpu from VTT is thanked for his help in assisting the practical implementation of the user study 2.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.foohum.2025.100802.

References

Arroyo, P. E., Liñan, J., & Vera Martínez, J. (2020). Who really values healthy food? *British Food Journal, 123*, 720–738. https://doi.org/10.1108/BFJ-04-2020-0328

Bailey, R. L., Leidy, H. J., Mattes, R. D., Heymsfield, S. B., Boushey, C. J., Ahluwalia, N., Cowan, A. E., Pannucci, T., Moshfegh, A. J., Goldman, J. D., Rhodes, D. G., Stoody, E. E., Jesus, J., & Casavale, K. O. (2022). Frequency of eating in the US population: A narrative review of the 2020 dietary guidelines advisory committee report. *Current Developments In Nutrition, 6*, Article nzac132. https://doi.org/10.1093/cdn/nzac132

Besharat, A., Romero, M., & Haws, K. (2021). Customizing calories: How rejecting (vs. selecting) ingredients leads to lower calorie estimation and unhealthier food choices. *Journal of Retailing, 97*, 424–438. https://doi.org/10.1016/j.jretai.2020.11.003

Bos, C., van der Lans, I. A., van Kleef, E., & van Trijp, H. C. M. (2018). Promoting healthy choices from vending machines: Effectiveness and consumer evaluations of four types of interventions. *Food Policy, 79*, 247–255. https://doi.org/10.1016/j.foodpol.2018.07.001

Calegari, L. P., & Fettermann, D. C. (2018). Mass customization in food production: A perception about the theme and future directions. *Product Management Development, 16*, 23–36. https://doi.org/10.4322/pmd.2018.005

Campbell, M. C., & Warren, C. (2015). The progress bias in goal pursuit: When one step forward seems larger than one step back. *Journal of Consumer Research, 41*, 1316–1331. https://doi.org/10.1086/679307

Caruso, M. L., Klein, E. G., & Kaye, G. (2014). Campus-Based snack food vending consumption. *Journal of Nutrition Education and Behavior, 46*, 401–405. https://doi.org/10.1016/j.jneb.2014.02.014

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*, 155–159. https://doi.org/10.1037/0033-2909.112.1.155

Derossi, A., Husain, A., Caporizzi, R., & Severini, C. (2020). Manufacturing personalized food for people uniqueness. An overview from traditional to emerging technologies. *Critical Reviews in Food Science and Nutrition, 60*, 1141–1159. https://doi.org/10.1080/10408398.2018.1559796

Enriquez, J. P., & Gollub, E. (2023). Snacking consumption among adults in the United States: A scoping review. *Nutrients, 15*, 1596. https://doi.org/10.3390/nu15071596

European Parliament and Council. (2006). Regulation (EC) No 1924/2006 of 20 December 2006 on nutrition and health claims made on foods. Official Journal of the European Union, L404, 9–25.

European Parliament and Council. (2011). Regulation (EU) No 1169/2011 on the provision of food information to consumers. Official Journal of the European Union, L304, 18–63.

Evans, C. E. L., Worth, S., White, R., & Strachan, E. K. (2023). Evaluation of an experiment to increase availability of healthier snack foods in vending machines situated within English sports facilities. *Public Health Nutrition, 26*, 3088–3099. https://doi.org/10.1017/S1368980023002069

Grech, A., Hebden, L., Roy, R., & Allman-Farinelli, M. (2017). Are products sold in university vending machines nutritionally poor? A food environment audit. *Nutrition and Dietetics, 74*, 185–190. https://doi.org/10.1111/1747-0080.12332

Hess, J. M., Jonnalagadda, S. S., & Slavin, J. L. (2016). What is a snack, why do we snack, and how can we choose better snacks? A review of the definitions of snacking, motivations to snack, contributions to dietary intake, and recommendations for improvement. *Advances in Nutrition, 7*, 466–475. https://doi.org/10.3945/an.115.009571

Kant, A. K., & Graubard, B. I. (2015). 40-Year trends in meal and snack eating behaviors of American adults. *Journal of the Academy of Nutrition and Dietetics, 115*, 50–63. https://doi.org/10.1016/j.jand.2014.06.354

Klesse, A. K., Cornil, Y., Dahl, D. W., & Gros, N. (2019). The secret ingredient is me: Customization prompts Self-Image-Consistent product perceptions. *Journal of Marketing Research, 56*, 879–893. https://doi.org/10.1177/0022243719846063

Lasala, C., Durán, A., Lledó, D., & Soriano, J. M. (2022). Assessment of nutritional quality of products sold in university vending machines according to the Front-of-Pack (FoP) guide. *Nutrients, 14*, 5010. https://doi.org/10.3390/nu14235010

Li, H., Liao, F., & Qing, P. (2022). How consumer expertise influences preference for customized food. *Foods, 11*, 2459. https://doi.org/10.3390/foods11162459

Lindner, J. (2024). Vending industry statistics. Retrieved from ⟨https://Worldmetrics.Org/Vending-Industry-Statistics/#sources⟩. Accessed August 14, 2024.

Ovaskainen, M. L., Tapanainen, H., & Pakkala, H. (2010). Changes in the contribution of snacks to the daily energy intake of Finnish adults. *Appetite, 54*, 623–626. https://doi.org/10.1016/j.appet.2010.03.012

Park, H., & Papadaki, A. (2016). Nutritional value of foods sold in vending machines in a UK university: Formative, cross-sectional research to inform an environmental intervention. *Appetite, 96*, 517–525. https://doi.org/10.1016/j.appet.2015.10.022

Prada, M., Saraiva, M., Sério, A., Coelho, S., Godinho, C. A., & Garrido, M. V. (2021). The impact of sugar-related claims on perceived healthfulness, caloric value and expected taste of food products. *Food Quality and Preference, 94*, Article 104331. https://doi.org/10.1016/j.foodqual.2021.104331

Stoyanov, D. (2021). The role of vending channels in marketing: A systematic review and taxonomy of studies. *Journal of Consumer Affairs, 55*, 654–679. https://doi.org/10.1111/joca.12362

TENK. (2019). The ethical principles of research with human participants and ethical review in the human sciences in Finland. In Publications of the Finnish National Board on Research Integrity (2nd ed., Vol. 3).

Ueland, Ø., Altintzoglou, T., Kirkhus, B., Lindberg, D., Rognså, G. H., Rosnes, J. T., Rud, I., & Varela, P. (2020). Perspectives on personalised food. *Trends in Food Science Technology, 102*, 169–177. https://doi.org/10.1016/j.tifs.2020.05.021

Vehmas, K., Calton, A., Grenman, K., Aisala, H., Sozer, N., & Nordlund, E. (2020). Development and consumer perception of a snack machine producing customized spoonable and drinkable products enriched in dietary fiber and protein. *Foods, 9*, 1–11. https://doi.org/10.3390/foods9101454

Vehmas, K., Lavrusheva, O., Seisto, A., Poutanen, K., & Nordlund, E. (2019). Consumer insight on a snack machine producing healthy and customized foods at point of consumption. *British Food Journal, 121*, 2551–2563. https://doi.org/10.1108/BFJ-01-2019-0033

Wang, W., Chen, Z., & Kuang, J. (2025). Artificial Intelligence-Driven recommendations and functional food purchases: Understanding consumer Decision-Making. *Foods, 14*, 976. https://doi.org/10.3390/foods14060976

Ziauddeen, N., Almiron-Roig, E., Penney, T. L., Nicholson, S., Kirk, S. F. L., & Page, P. (2017). Eating at food outlets and "on the go" is associated with less healthy food choices in adults: Cross-sectional data from the uk national diet and nutrition survey rolling programme (2008–2014). *Nutrients, 9*, 1–17. https://doi.org/10.3390/nu9121315

Web references

just baked smart bistro. Retrieved from ⟨https://www.justbakedkiosk.com/⟩, accessed April 2, 2024.

Bake Xpress. Retrieved from ⟨https://www.lebreadxpress.com/⟩, accessed April 2, 2024.

Fizza. Retrieved from ⟨https://en.fizza.fi⟩, accessed August 14, 2024.

BreadBot. Retrieved from ⟨https://www.wilkinsonbaking.com/breadbot-information⟩, accessed April 2, 2024.

Cloudpick. Retrieved from ⟨https://www.cloudpick.ai⟩, accessed July 2, 2025.