

Cross-national differences in consumer responses to savoury crackers containing blackcurrant pomace

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Abstract

Juice pressing residues, among them blackcurrant pomace, are valuable materials for being upgraded in food products. Their excellent nutritional profiles in line with their functional properties allow a wide range of applications. The current study was performed to evaluate the overall liking of a pomace enriched thin crispy baked bread product in five European countries, and to obtain suggestions for improvements. Moreover data on the frequency of snack consumption, openness to new foods, and an opinion on residues in food applications were acquired. Four hundred and sixty-six consumers from United Kingdom, Spain, Sweden, Italy, and Germany were involved. On a 9-point hedonic scale, the pomace cracker was rated towards the direction of liking with 5.94 ± 1.90 on average. Contingency tables showed that the overall liking correlated highly significant ($p < 0.01$) with the country of origin and sex of the respondents and their openness to new products. Significantly higher liking scores were provided by British and Spanish consumers and, among these respondents, savoury snacks were stated to be consumed most frequently. Therefore, the snack consumption frequency also appeared to be a driver for cross national differences in hedonic responses. The consent for using pomace in food products was remarkably high (> 90%) in all countries and stresses consumer awareness in terms of healthy longevity and sustainability.

1. Introduction

Nowadays there is a common agreement that the increase of the world's population and climate changes call for an adaptation of food production, and an increase of resource efficiency is one of the key aspects. In this context, the valorisation of food processing by-products such as press cakes from oil processing or pomace from fruit or vegetable juice manufacture is not only beneficial in the holistic sense, using all components in food systems, but also allows to take advantage from beneficial nutritional compounds that are part of these materials.

After processing berries to juice, the remaining pomace contains 50 – 75% moisture (Reißner *et al.*, 2019; Ross *et al.*, 2020). This broad variation can partly be attributed to berry variety, but also to processing conditions (e.g., temperature, use of enzymes; Vagiri and Jensen, 2017). Berry pomace is rich in dietary fibre, contains valuable proteins and oils, and phytochemicals with high antioxidant capacity (Struck *et al.*, 2016; Reißner *et al.*, 2019). However, sensory and technological obstacles must be overcome before berry pomace can successfully be utilized in food systems. Sandell *et al.* (2009) evaluated the orosensory profile of blackcurrant pomace fractions. Total intensity of pomace flavour was milder than that of the juice because the residue lacks of sugars and acids that account for a fruity, sweet, and sour flavour. Although the remaining phenolic compounds were expected to reinforce bitterness and astringency the dry pomace was, in contrast to its ethanolic extracts, less intense.

As regards technological aspects, immediate drying is necessary to ensure an appropriate shelf life of the resulting pomace powder. In addition, applicability may be improved by subsequent milling or the removal of seeds. From a sensory point of view, prospective consumers should be involved in product development: Not only to gain insight into their opinion on new food formulations, but also to evaluate their attitudes concerning the recycling of production losses and a sustainable and healthy diet. Indeed, new food products can only survive on the market if they fulfil consumer expectations and meet hedonic requirements (Saint-Eve *et al.*, 2019). Moreover, consumers find it more reasonable to enrich unhealthy foods with valuable ingredients rather than products that are commonly considered as healthy (Annunziata and Vecchio, 2013).

It is generally known that eating habits, food aversions and hedonic preferences differ between countries, populations or cultures (Zellner *et al.*, 1999; Baharuddin and Sharifudin, 2015). In this context, several questionnaire-based studies focused on the evaluation of attitudes towards visually suboptimal foods (de Hooge *et al.*, 2017), on the acceptance of meat replacement by plant proteins (Banovic and Sveinsdóttir, 2021), on the importance of texture contrasts in foods (Pellegrino *et al.*, 2020), or on aspects of cultured meat (Siegrist

and Hartmann, 2020; Hansen *et al.*, 2021). Not least because of the high effort, cross-cultural consumer studies with real products are notably more challenging. Among studies aiming at assessing cultural differences in consumers responses, Bonany *et al.* (2013) investigated the acceptance of new apple varieties in seven European countries by taking responses from more than 4000 consumers. Cicatiello *et al.* (2020) investigated the liking of insect-based snacks among young Italian consumers (n=62) in the context of cultural barriers on insect-based foods. Wong *et al.* (2020) recruited 172 participants from Korea, China, and the US and investigated texture preferences for commercially available dried fruits. Laaksonen *et al.* (2020) combined questionnaire responses with real product evaluations carried out in Finland and China (241 consumers in total) to identify the pleasantness of oat products in these two markets.

In our previous studies, we analysed effects of replacing formulation constituents (flour, sugar, or fat) by blackcurrant pomace at different levels on the properties of baked products (Diez-Sánchez *et al.*, 2018, 2019; Quiles *et al.*, 2018; Reißner *et al.*, 2020; Schmidt *et al.*, 2018; Tarrega *et al.*, 2017). It was shown that it was possible to replace up to 30% flour with pomace powder in sponge cake formulations (Quiles *et al.*, 2018). Currant or chokeberry pomace had opposite effects on the texture of soft cakes, depending on the ingredients that were targeted for replacement: when flour was reduced in formulations, the crumb became softer while sugar replacement caused an increased hardness, and reducing fat showed intermediate effects (Quiles *et al.*, 2018). Baked products enriched with currant pomace appeared in extraordinary colours. For instance, dark purple wheat dough resulted in greyish bread crumb (Reißner *et al.*, 2020), and the red colour fraction in crackers became more prominent when currant pomace was added (Schmidt *et al.*, 2018). Accordingly, Schmidt *et al.* (2018) found among German consumers that the general acceptance of a cracker formulation with 20% pomace did not differ significantly from the reference, and that additional topping of the crackers with sesame seeds raised hedonic responses.

In the light of the above, savoury crackers enriched with blackcurrant pomace were selected in the present study for sensory evaluation in five European countries. A reference was excluded as the formulation with pomace and sesame seeds performed even better in our previous study (Schmidt *et al.*, 2018). The chosen snack product consisted solely of vegetable ingredients and thus can be labelled as vegan and, additionally by the use of the sustainable by-product, as "high in dietary fibre". Following the Merriam-Webster dictionary, crackers are defined as "a dry thin crispy baked bread product that may be leavened or unleavened".

The aim of the present study was to evaluate the overall liking of the crackers in the United Kingdom, Spain, Sweden, Italy, and Germany. From the results we expect to obtain

information on presumable cross-national differences among the targeted groups, which may help to draw conclusions for future applications of fruit by-products in food systems. Moreover, data on the frequency of snack consumption, openness to new foods, and an opinion on residues as food applications were acquired.

2. Materials and methods

2.1 Sample preparation and presentation

Savoury crackers were prepared as described by Schmidt et al. (2018), with 20% of the regular amount of flour replaced by blackcurrant pomace. The pomace obtained from Döhler Neuenkirchen GmbH (Neuenkirchen/Cuxhaven, Germany) was dried in a convection oven for 2 h at 70 °C and subsequently milled using a ZM 100 ultra-centrifugal mill (Retsch GmbH, Haan, Germany), with the resulting powder showing a moisture content of 11% and a particle size < 500 µm. As per kg dough, the cracker formulation comprised 271 g wheat flour, 163 g buckwheat flour, 108 g blackcurrant pomace, 322 g water, 90 g olive oil, 18 g sucrose, 14 g sodium chloride, and 14 g ammonium bicarbonate. After mixing and final kneading (for details, see Schmidt et al., 2018), the dough was sheeted to a thickness of 1.8 mm using a mechanical dough sheeter (Econom STM 5303, RONDO Burgdorf AG, Burgdorf, Switzerland) and cut into 35 x 35 mm² sections. These were then manually besprinkled with sesame seeds, and baked at 200 °C for 13 min in a MIWE conduction oven (Michael Wenz GmbH, Arnstein, Germany). After cooling, the crackers were hermetically sealed in plastic bags and shipped via express delivery from Germany to the participating universities. During production, baking, and distribution of the samples, all hygienic and safety regulations for food production were followed. At the respective evaluation site, three crackers were provided to each participant in a sealable transparent polypropylene bag (70 x 100 mm²). The respondents received a serving unit concomitantly with the questionnaire that informed them on cracker ingredients and confidential handling of the data.

2.2 Participants

On a voluntary basis, 491 participants were recruited in canteens or cafeterias located on the campus of five universities in Dresden/Germany (DE), Valencia/Spain (SP), Lund/Sweden (SE), Milano/Italy (IT), and Huddersfield/United Kingdom (UK). The number of participants comprised of the volunteers that were recruited in one testing session at each location. Since twenty-five incomplete response forms had to be excluded from analysis, data of 466 respondents ($n_{DE} = 95$; $n_{SP} = 108$; $n_{SE} = 60$; $n_{IT} = 116$; $n_{UK} = 87$) were finally analysed. Descriptive statistics on geographical origin, age, sex, and occupation are displayed in **Table 1**. Prior to participation, all subjects gave informed consent and agreed to the study

conditions. The study was approved by the Ethics Commission of TU Dresden, reference number EK 88032018.

2.3 Study design

The questionnaire was set up in German, translated into English (UK, SE), Spanish or Italian, and preliminary tested by thirty individuals in Germany. The respondents were informed on the product under study by disclosing its ingredients, and they were asked to taste the cracker and rate overall liking on a 9-point hedonic scale. Smileys symbolized the anchor "dislike extremely" (1), the scale midpoint "neither like nor dislike" (5) and the anchor "like extremely" (9) (Lim, 2011). After tasting was completed, the participants were asked to give their opinion on any desirable product improvements. Concluding the product-related factors, free suggestions could be made with respect to shape, colour, smell, texture, flavour, and the topping.

The next section of the questionnaire aimed at disclosing person-related factors. After providing personal information on age, sex, and occupation, the respondents were finally invited to estimate their individual consumption frequency of savoury snacks by choosing one of four given options and to indicate their general openness to new products on a 5-point scale anchored with "not at all" (left side) and "very much" (right anchor).

A final statement referred to berry pomace as a by-product of fruit processing and an opinion was requested on the use of such a residue in foods (yes or no). The full wording of this section was: "Fresh fruits are eaten as a whole, and in jams berry fruits are consumed completely, whereas after juicing, skins and seeds are leftovers. The previously tasted product contained such a residue. Do you favour the application of such residues in foods?" Finally, the respondents had the possibility for giving their further opinion in a comment section.

2.5 Statistical analysis

Statistical analysis of the questionnaire responses was conducted using SPSS 25 (IBM Deutschland GmbH, Ehningen, Germany). Contingency tables were set up and categorical variables were tested for relationships using Pearson's χ^2 and Cramér's V. When prerequisites such as asymptotic distribution for interpretation were not met, variables were summarized and Fisher's exact test was applied. In detail, the 9-point scale for overall liking was condensed to a 7-point scale by combining the two outer points on each end of the scale (Lawless and Heymann, 2010). The age of the respondents was classified into three segments (age 18 – 25; 26 – 45; > 45), and information on occupation to "in training" and "other". Openness to new products was categorized in three increments, where the highest

consent "very much" remained unchanged, the second best rating was labelled with "quite well", and the three poorest ratings were dichotomized to "somewhat/not at all". Analysis of variance with subsequent Bonferroni post hoc-testing at $p \leq 0.05$ was conducted with SAS University Edition 6p.2 (SAS Institute Inc., Cary, USA) to identify origin-related differences in overall liking, and one sample t -tests were calculated with Microsoft Excel (2013) to compare the average liking with the scale midpoint.

3. Results

3.1 Product-related factors

The overall acceptance (**Figure 1**) of the savoury pomace crackers was rated 5.94 ± 1.90 on average and a t -test against the scale midpoint ($= 5$) showed a significant ($p < 0.05$) trend towards the direction of liking. This significance in liking was evident through all individual countries except for Italy, where the respondents neither liked nor disliked the product ($p > 0.05$). Undertaken geography based likeness preferences for functional crackers revealed that the proportion of respondents that liked/extremely liked the cracker was highest in the UK and in Spain ($p < 0.05$). Although the overall perception was positive, 85% of all respondents took the opportunity and made recommendations with respect to desirable product improvements.

Seven criteria (shape, colour, smell, texture, flavour, sprinkling, other) served as suggestions for freely written answers, e.g. "saltier", "less brown", or "more seeds". Overall, the frequency of suggestions appeared to be independent from the respondents' origin. Flavour was most frequently addressed, in fact by 52% of the respondents ($n = 242$), while the other criteria for recommendations were used by, on average, 8.4 – 23.2% of the respondents (**Figure 2, Table 2**). Especially German consumers complained about the lack of intense flavour and demanded saltier (52.2% of nominations), spicier (13.4%), and fruitier products (11.9%), but were satisfied with cracker dimensions (not indicated by 91.6%). Pertinent suggestions, indicated by more than $> 5\%$ of all respondents, are displayed in **Table 2**. Because of the small numbers of indications in single attributes, the distribution was not broken down to respective countries. In total, 11.2% and 5.8% requested bigger and/or thicker crackers, respectively, which accounts for more than 80% of the nominations for the aspect "shape". The dark brown colour was critically addressed by fifty-three respondents (11.4%), which is a majority for the colour aspect. Out of forty respondents (8.6% of all participants) that requested improvements in smell, 70% asked for an increased fruity, bread-like, or aromatic odour. These demands were also reflected by the flavour attributes. More than one out of five requested saltier, 5.6% ($n = 26$) requested more aromatic and spicier, and still 3.9% ($n = 18$) requested fruitier crackers. The perception of bitterness and a

roasted after-taste differed among the countries and was criticized by 23.7% of nominations in Spain, 18.4% in the UK, but only 4.5, 6.7, and 10.4% in Germany, Sweden, and Italy, respectively. The proportion of respondents that suggested a change without specifying the answer was remarkably high in the flavour category, indicating that respondents were not pleased with the flavour or maybe their expectations have not been matched. Concerning texture, > 70% of the nominations asked for more crispness, making up 16.3% (n = 76) of all respondents.

From 15% (n = 70) of respondents who suggested modifications of the topping, three nominations were balanced: more sesame, no/less sesame, and the use of other toppings. Remarkably, not a single respondent in Germany annotated less sesame and no-one from Sweden asked for more sesame seeds. Proposals for alternative toppings were pumpkin, chia, sunflower or poppy seeds, pistachio or pine nuts, but also cheese or grains of salt. Entries in the category "other" included suggestions such as the incorporation of different fruit residues, consumption of the crackers with a spread or dip, a reduction of sugar in the formulation, or avoiding plastic as packaging material.

3.2 Person-related factors

Overall, the respondents in this study were predominantly young students with a balanced sex ratio (see **Table 1**). However, there were some differences between the participating countries. Employees aged between 26 and 45 years dominated in Sweden and UK, while students aged 18 – 25 years were overrepresented in Italy. Furthermore, significantly more men than women participated in Sweden ($p < 0.05$). The proportion of respondents that indicated a general openness to new foods in the self-assessment ranged, depending on location, from 77.9 – 92.0% (in ascending order: DE, IT, SE, ES, UK). Only 1.3% of all respondents declared to absolutely reject new products.

About 72% of respondents indicated that they consume savoury snacks once per month at minimum and 35.8% even up to several times a week. Especially in the UK, such snacks were stated to be consumed most frequently while, in the other countries, a consumption frequency of less than 1 – 3 times per month dominated. Respondents from Italy were the least familiar with the product category under study, with 11.2% mentioning that they never eat savoury snacks.

On average, 95.3% of all respondents favoured the idea of recycling fruit juice pressing residues and its potential application in foods. The consent ranged on the same statistical level between 92.0% in UK and 100% in Spain but was significantly lower in Italy (90.5%, $p < 0.05$).

The opportunity for giving final remarks was taken by, on average, every seventh respondent. This proportion was highest in the UK (25.3%) and lowest in Italy (4.3%). The individual comments were assigned to four categories: "consent to the use of by-products" (51.5% of nominations), "indication of liking" (42.2%), "critical notes" (16.7%), and "other" (6.1%). The total of more than 100% derives from individual responses to more than one category. Statements from a particular respondent, for instance "good idea, great product" and "I do not see why they (the by-products) should not be used. I also consider them good because it has fibre. I have liked the snack very much and even more when knowing that it contains by-products" were counted both, in the first and second category, respectively. With a few exceptions, all critical notes emphasized the necessity for a more intense or different flavour. One respondent denoted that more information on pressing residues is required for forming an opinion; another stated an indifferent opinion concerning this topic. Other aspects that were addressed concerned health benefits such as energy and fibre content, and favouring natural ingredients was also stressed. Finally, biodegradable packaging was mentioned in this context.

3.3 Connection between data collected on pomace crackers and respondents

Table 3 displays independencies and potential correlations between the considered variables. First of all, respondents that indicated higher overall liking of the crackers suggested fewer adjustments. A lower overall liking can be linked to a higher frequency of suggestions for improvements in flavour, texture, and smell, whereas no significances were found for the cracker aspects shape, colour, sprinkling, and other suggestions. Cramér's V (CV), a measure of association, between overall liking and flavour was remarkably strong (0.375) and highly significant ($p = 0.000$). In contrast, connections of overall liking to age, occupation, and eating habits were less pronounced. Young respondents and concurrent students, as well as persons never eating savoury snacks tended to rate the cracker poorly. Most likely, overall liking also depended on sex and origin. Rather women preferred the cracker, and the acceptance in the different countries decreased in the order of UK, ES, DE, SE, and IT (see **Figure 1**). As dominantly women stated a positive attitude towards new foods, this attribute consequently affected overall liking. The frequency of cracker consumption correlated with the origin of the respondent, and participants periodically eating snacks were more open for new products (**Figure 3**). The Marimekko diagram stresses the high proportion of British respondents that were very open to new products, and illustrates the overall tendency that infrequent snack consumption is accompanied with a reduced curiosity for new products. Finally, the self-reported favour for pomace application showed weak associations with openness to new products (CV = 0.137) and the origin of the

respondents (CV = 0.180, see **Table 3**). All other attributes appeared to be independent of each other ($p > 0.05$), for example no associations of socio-demographic aspects with suggested improvements were observed.

4. Discussion

The overall liking of the crackers significantly depended on testing location and, therefore, on nutrition habits in the respective countries. It is evident that frequent snack consumption accompanied by a familiarity with blackcurrants served as booster for general acceptance. This is true for the UK, where the crackers were rated with highest overall liking and also explains the decreased acceptance in Italy, where consumers are less familiar with currants in general and only occasionally consume savoury snacks (Camara, 2020; Wollbold and Behr, 2020).

In Germany, Spain, and Sweden only one of these aspects is relevant, either a familiarity with savoury snacks, or with blackcurrants: currants and their products are habitual elements in the Swedish and German diet with a per capita consumption of 4.8 and 1.8 kg in 2018, respectively (BMEL, 2019; SCB, 2019). Consumption of berries in Spain is relatively high for strawberries and grapes, but no numbers for blackcurrant could be found (Mercasa, 2020; Statista, 2020). Therefore, the snack consumption frequency queried in this study seems to have a larger effect on the overall liking than the per capita consumption of currants and is a decisive criterion in Spain. Johnson and Anderson (2010) summarized that not only snack consumption increased since decades among young adults but also that the energy uptake per snacking occasion became higher. Especially the diet of university students seems to include too much fat and an insufficient amount of vegetables, as was shown among Italian and Spanish students (Baldini *et al.*, 2009). In Sweden and Germany, savoury crackers are more frequently consumed by young people, too (Mensink and Burger, 2002; Bertéus Forslund *et al.*, 2005). However, a multi-year study from 2014-2017 showed that the number of adolescents in Germany consuming one or more snacks per day decreased since 2003-2006 from 64% in average to 51% (RKI, 2020). As regards the criteria for cracker improvement, flavour was suggested most frequently. Schmidt *et al.* (2018) compared pomace crackers with a pomace-free reference in a sensory profile analysis using a trained panel. After subjecting the resulting data to principle component analysis, they observed a decreased perception of saltiness and sweetness in pomace-containing crackers. Furthermore, a fruity and acidic smell and taste were attributes that were associated with the pomace crackers. A reduction in perceived saltiness was also found in this consumer study, but some of the respondents criticized the lack of a fruity flavour. The intensity of fruitiness may be less apparent for consumers, for one as their sensitivity might be lower than that of a

sensory expert. For the other, blackcurrant pressing residues, which were listed as cracker ingredients, could have provoked expectations that were not fulfilled. As Sandell *et al.* (2009) pointed out, the pressing residues of blackcurrants were less intense in flavour than the juice. However, the aroma profile of bread with pomace dietary fibre was expanded by more than 100 volatiles (Alba *et al.*, 2020). Preliminary experiments also revealed that a dark brown colour of crackers evokes associations to cocoa as ingredient. To avoid expecting sweet cookies, the participants of this study received a detailed description of the cracker and were informed on its savoury taste. In addition, the sesame topping was used for the same reason. However, a few respondents (n = 4) still associated the dark colour with chocolate flavour before tasting and were consequently disappointed. Indicators for such confusion were comments like “they seem to be chocolate cookies” or “looks like chocolate”.

The lack of specific comments after suggesting particular aspects for product improvement are likely to be evoked by uncertainties in sensory terminology and difficulties of matching own expectations with effects of detailed suggestions. While the respondents indicated mostly precise suggestions in the categories shape, texture, and topping, they lacked imagination with respect to smell and flavour.

The suggestions made for cracker improvement were partially contradictory, and presumably linked to individual preferences. For example, 4.9% of the participants requested no or less sesame on the crackers opposed to 4.1% who asked for more sesame. Summarizing the aspects proposed in the survey and comparing them with overall liking, increased crispiness, saltiness, and aromatic flavour and smell will prospectively improve general acceptance of the cracker. Steenkamp (1997) reported that consumption habit is a higher evaluative criterion for product choice in Italy than in the UK, Spain, and Germany. The flavour of the crackers used in this study apparently matched less with the expectations and longings of Italian respondents with their unique mediterranean lifestyle (Baldini *et al.*, 2009) even if a previous online survey on the preferences of Italian consumers reported a positive attitude for sustainable and organic farming (Annunziata and Vecchio, 2016). In contrast, local and sustainably produced foods are currently gaining more attention in Sweden, independently of age, income, and household size of the consumers (Bosona and Gebresenbet, 2018). However, this positive attitude towards organic foods not automatically promotes purchases of sustainable products (Magnusson *et al.*, 2001), as purchase decisions are highly related to food quality and price (Magnusson *et al.*, 2001; Bosona and Gebresenbet, 2018). In a previous study on pomace enriched soft cakes, the products were appealing to Spanish consumers (scoring 6-7 on a 9-point hedonic scale), which was also reflected by their purchase intention (Quiles *et al.*, 2018). Approximately 50% stated their willingness for buying the product and another 30% indicated “maybe”. The similar scoring in

overall liking of the crackers in this study can lead to the presumption that purchase intentions can be expected in a similar magnitude. There are repeated indications in literature that the eating behaviour differs between males and females (Cruwys *et al.*, 2015; Stok *et al.*, 2017; Symmank *et al.*, 2017). For instance, Ares and Gámbaro (2007) observed a more positive attitude of women towards fibre enriched products and Bosona and Gebresenbet (2018) reported an increased awareness of sustainability for females. Although it was not mentioned in the questionnaire, the pomace powder induced a dietary fibre supplementation. As indicated in the comment section, individual female respondents assumed this fact automatically. It is for thus a possible reason why women tended to provide higher hedonic ratings to the crackers compared to men.

Also, openness to new products and frequent snack consumption emerged as indicators for an increased overall liking. In addition, product familiarity changes an individual's valuation basis and influences quality assessment of foods (Giacalone and Jaeger, 2016). In case of the products used in this study, the blackcurrant pomace changed the cracker characteristics (Schmidt *et al.*, 2018) from a typical savoury snack to a commercially unknown product by introducing a darker colour and fruity taste. Being curious and open-minded apparently contributed to accepting these differences.

Another socio-demographic aspect that may have influenced the assessment of the crackers is the education level. As reported by Steenkamp (1997), educated persons (and, similarly, young consumers) rely on ethical criteria and neutral information more than on commercial sources. Favouring pomace application to prevent food losses could have been particularly pronounced among the students and graduates in this study. Anyway, the short explanation about berry pomace turned out to be promising for forming a first opinion on pressing residues. On account of missing information on processing, less sustainable foods may be favoured in situations of purchase (Magnusson *et al.*, 2001). Siegrist *et al.* (2015) assumed that environmentally responsible consumer behaviour will increase in consequence of awareness campaigns.

In conclusion, such an honest marketing strategy could be directive when introducing pomace in commercial food products and might prevent rejection of consumers about using residues or – in their view – waste. It is therefore highly recommendable to directly address the individual consumer's awareness towards sustainability and healthy nutrition in product marketing. In addition, new products and advertising strategies should be tailored to the different eating habits of the respective cultures.

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Declaration of competing interests

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. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Ethical statement

The experimental protocol was approved by the Ethics Commission of TU Dresden, reference number EK 88032018.

References

- Alba, K., Rizou, T., Paraskevopoulou, A., Campbell, G.M. & Kontogiorgos, V. (2020). Effects of blackcurrant fibre on dough physical properties and bread quality characteristics. *Food Biophysics*, **15**, 313–322.
- Annunziata, A. & Vecchio, R. (2013). Consumer perception of functional foods: A conjoint analysis with probiotics. *Food Quality and Preference*, **28**, 348–355.
- Annunziata, A. & Vecchio, R. (2016). Organic farming and sustainability in food choices: An analysis of consumer preference in Southern Italy. *Agriculture and Agricultural Science Procedia*, **8**, 193–200.
- Ares, G. & Gámbaro, A. (2007). Influence of gender, age and motives underlying food choice on perceived healthiness and willingness to try functional foods. *Appetite*, **49**, 148–158.
- Baharuddin, A.R. & Sharifudin, M.S. (2015). The impact of geographical location on taste sensitivity and preference. *International Food Research Journal*, **22**, 731–738.

Baldini, M., Pasqui, F., Bordoni, A. & Maranesi, M. (2009). Is the Mediterranean lifestyle still a reality? Evaluation of food consumption and energy expenditure in Italian and Spanish university students. *Public Health Nutrition*, **12**, 148–155.

Banovic, M. & Sveinsdóttir, K. (2021). Importance of being analogue: Female attitudes towards meat analogue containing rapeseed protein. *Food Control*, **123**, 107833.

Bertéus Forslund, H., Torgerson, J.S., Sjöström, L. & Lindroos, A.K. (2005). Snacking frequency in relation to energy intake and food choices in obese men and women compared to a reference population. *International Journal of Obesity*, **29**, 711–719.

Bonany, J., Buehler, A., Carbó, J., Codarin, S., Donati, F., Echeverria, G., Egger, S., Guerra, W., Hilaire, C., Höller, I., Iglesias, I., Jesionkowska, K., Konopacka, D., Kruczyńska, D., Martinelli, A., Pitiot, C., Sansavini, S., Stehr, R. & Schoorl, F. (2013). Consumer eating quality acceptance of new apple varieties in different European countries. *Food Quality and Preference*, **30**, 250–259.

Bosona, T. & Gebresenbet, G. (2018). Swedish consumers' perception of food quality and sustainability in relation to organic food production. *Foods*, **7**, 54.

Camara, S. (2020). Customized report service – Healthy snacks in France and Belgium. <https://www.agr.gc.ca/eng/international-trade/market-intelligence/reports/customized-report-service-healthy-snacks-in-france-and-belgium/?id=1589197791889> (Accessed 22 June 2021)

Cicatiello, C., Vitali, A. & Lacetera, N. (2020). How does it taste? Appreciation of insect-based snacks and its determinants. *International Journal of Gastronomy and Food Science*, **21**, 100211.

Cruwys, T., Bevelander, K.E. & Hermans, R.C.J. (2015). Social modeling of eating: A review of when and why social influence affects food intake and choice. *Appetite*, **86**, 3–18.

Diez-Sánchez, E., Llorca, E., Quiles, A. & Hernando, I. (2018). Using different fibers to replace fat in sponge cakes: In vitro starch digestion and physico-structural studies. *Food Science and Technology International*, **24**, 533–543.

Diez-Sánchez, E., Quiles, A., Llorca, E., Reißner, A.-M., Struck, S., Rohm, H. & Hernando, I. (2019). Extruded flour as techno-functional ingredient in muffins with berry pomace. *LWT*, **113**, 108300.

German Federal Ministry of Food and Agriculture (BMEL). (2019). Pro-Kopf-Verbrauch von Obst nach Arten. <https://www.bmel-statistik.de/fileadmin/daten/GBT-0070002-2019.pdf> (Accessed 12 April 2021)

Giacalone, D. & Jaeger, S.R. (2016). Better the devil you know? How product familiarity affects usage versatility of foods and beverages. *Journal of Economic Psychology*, **55**, 120–138.

Hansen, J., Sparleanu, C., Liang, Y., Büchi, J., Bansal, S., Caro, M.Á. & Staedtler, F. (2021). Exploring cultural concepts of meat and future predictions on the timeline of cultured meat. *FUFO-D-20-00113R2*.

Hooge, I.E. de, Oostindjer, M., Aschemann-Witzel, J., Normann, A., Loose, S.M. & Almlí, V.L. (2017). This apple is too ugly for me! *Food Quality and Preference*, **56**, 80–92.

Johnson, G.H. & Anderson, G.H. (2010). Snacking definitions: Impact on interpretation of the literature and dietary recommendations. *Critical Reviews in Food Science and Nutrition*, **50**, 848–871.

Laaksonen, O., Ma, X., Pasanen, E., Zhou, P., Yang, B. & Linderborg, K.M. (2020). Sensory characteristics contributing to pleasantness of oat product concepts by Finnish and Chinese consumers. *Foods*, **9**, 1234.

Lawless, H.T. & Heymann, H. (2010). *Sensory evaluation of food: Principles and practices*. Food science text series. 2nd edn. New York: Springer.

Lim, J. (2011). Hedonic scaling: A review of methods and theory. *Food Quality and Preference*, **22**, 733–747.

Magnusson, M.K., Arvola, A., Koivisto Hursti, U., Åberg, L. & Sjöden, P. (2001). Attitudes towards organic foods among Swedish consumers. *British Food Journal*, **103**, 209–227.

Mensink, G.B.M. & Burger, M. (2002). *Was essen wir heute? Ernährungsverhalten in Deutschland*. Beiträge zur Gesundheitsberichterstattung des Bundes. Berlin: Robert-Koch-Inst.

Mercasa. (2020). Alimentación en España 2020. https://www.mercasa.es/media/publicaciones/281/AEE_2020_web.pdf (Accessed 12 April 2021)

Merriam-Webster.com. (2021). cracker. <https://www.merriam-webster.com/dictionary/cracker> (Accessed 21 July 2021)

Pellegrino, R., Cheon, B.K., Forde, C.G., Oleszkiewicz, A., Pieniak, M. & Lockett, C.R. (2020). The contribution of texture contrasts and combinations to food acceptance across cultures. *Journal of Texture Studies*, **51**, 225–231.

Quiles, A., Llorca, E., Schmidt, C., Reißner, A.-M., Struck, S., Rohm, H. & Hernando, I. (2018). Use of berry pomace to replace flour, fat or sugar in cakes. *International Journal of Food Science & Technology*, **53**, 1579–1587.

Reißner, A.-M., Al-Hamimi, S., Quiles, A., Schmidt, C., Struck, S., Hernando, I., Turner, C. & Rohm, H. (2019). Composition and physicochemical properties of dried berry pomace: Composition and technofunctional properties of berry pomace. *Journal of the Science of Food and Agriculture*, **99**, 1284–1293.

Reißner, A.-M., Beer, A., Struck, S. & Rohm, H. (2020). Pre-hydrated berry pomace in wheat bread: An approach considering requisite water in fiber enrichment. *Foods*, **9**, 1600.

Robert Koch Institute (RKI). (2020). AdiMon-Themenblatt: Verzehr von Süßwaren und Knabberartikeln. https://www.rki.de/DE/Content/Gesundheitsmonitoring/Studien/Adipositas_Monitoring/Verhalten/HTML_Themenblatt_Suesswaren.html (Accessed 2 June 2021)

Ross, K.A., DeLury, N., Fukumoto, L. & Diarra, M.S. (2020). Dried berry pomace as a source of high value-added bioproduct: drying kinetics and bioactive quality indices. *International Journal of Food Properties*, **23**, 2123–2143.

Saint-Eve, A., Granda, P., Legay, G., Cuvelier, G. & Delarue, J. (2019). Consumer acceptance and sensory drivers of liking for high plant protein snacks. *Journal of the Science of Food and Agriculture*, **99**, 3983–3991.

Sandell, M., Laaksonen, O., Järvinen, R., Rostiala, N., Pohjanheimo, T., Tiitinen, K. & Kallio, H. (2009). Orosensory profiles and chemical composition of black currant (*Ribes nigrum*) juice and fractions of press residue. *Journal of Agricultural and Food Chemistry*, **57**, 3718–3728.

This paper demonstrates the great potential of blackcurrant residues as food ingredient and therefore is reasonable for gaining attention. It offers valuable background in sensory perception for the current study.

Schmidt, C., Geweke, I., Struck, S., Zahn, S. & Rohm, H. (2018). Blackcurrant pomace from juice processing as partial flour substitute in savoury crackers: dough characteristics and product properties. *International Journal of Food Science & Technology*, **53**, 237–245.

This paper investigated the effects of blackcurrant pomace on physical properties of the respective dough and baked products. First indications on sensory acceptance were evaluated and they formed the basis for this study.

Siegrist, M. & Hartmann, C. (2020). Perceived naturalness, disgust, trust and food neophobia as predictors of cultured meat acceptance in ten countries. *Appetite*, **155**, 104814.

Siegrist, M., Visschers, V.H.M. & Hartmann, C. (2015). Factors influencing changes in sustainability perception of various food behaviors: Results of a longitudinal study. *Food Quality and Preference*, **46**, 33–39.

The researchers from ETH Zurich explored changes in food behaviours in a longitudinal panel study. Their findings may help to understand consumer behaviour, and how to increase individual's awareness on sustainability.

Statista. (2020). Volumen de frutas consumidas per cápita en España en 2019, por producto. <https://es.statista.com/estadisticas/494036/consumo-per-capita-frutas-espana/> (Accessed 12 April 2021)

Statistics Sweden (SCB). (2019). Food consumption and nutritive values, data up to 2018. https://www.scb.se/contentassets/8af9fcac17634fc197825dfec6e2b0ce/jo1301_2018a01_sm_jo44sm1901.pdf (Accessed 12 April 2021)

Steenkamp, J.-B.E. (1997). Dynamics in consumer behavior with respect to agricultural and food products. In: *Agricultural marketing and consumer behavior in a changing world*. Pp. 143–188. Springer.

Stok, F.M., Hoffmann, S., Volkert, D., Boeing, H., Ensenauer, R., Stelmach-Mardas, M., Kiesswetter, E., Weber, A., Rohm, H., Lien, N., Brug, J., Holdsworth, M. & Renner, B. (2017). The DONE framework: Creation, evaluation, and updating of an

interdisciplinary, dynamic framework 2.0 of determinants of nutrition and eating. *PLOS ONE*, **12**, e0171077.

Struck, S., Plaza, M., Turner, C. & Rohm, H. (2016). Berry pomace - a review of processing and chemical analysis of its polyphenols. *International Journal of Food Science & Technology*, **51**, 1305–1318.

This review contains well-researched and organized data on berry by-products and recommendations for their processing to gain new materials for food applications. The study draws attention to their valuable nutritional components and stimulated our research on blackcurrant pomace.

Symmank, C., Mai, R., Hoffmann, S., Stok, F.M., Renner, B., Lien, N. & Rohm, H. (2017). Predictors of food decision making: A systematic interdisciplinary mapping (SIM) review. *Appetite*, **110**, 25–35.

Tarrega, A., Quiles, A., Morell, P., Fiszman, S. & Hernando, I. (2017). Importance of consumer perceptions in fiber-enriched food products. A case study with sponge cakes. *Food & Function*, **8**, 574–583.

Vagiri, M. & Jensen, M. (2017). Influence of juice processing factors on quality of black chokeberry pomace as a future resource for colour extraction. *Food Chemistry*, **217**, 409–417.

Wollbold, W. & Behr, H.-C. (2020). European Statistics Handbook. https://www.scb.se/contentassets/8af9fcac17634fc197825dfec6e2b0ce/jo1301_2018a01_sm_jo44sm1901.pdf (Accessed 12 April 2021)

Wong, R., Kim, S., Chung, S.-J. & Cho, M.-S. (2020). Texture preferences of Chinese, Korean and US consumers: A case study with apple and pear dried fruits. *Foods*, **9**, 377.

Zellner, D., Garriga-Trillo, A., Rohm, E., Centeno, S. & Parker, S. (1999). Food liking and craving: A cross-cultural approach. *Appetite*, **33**, 61–70.

Figure captions

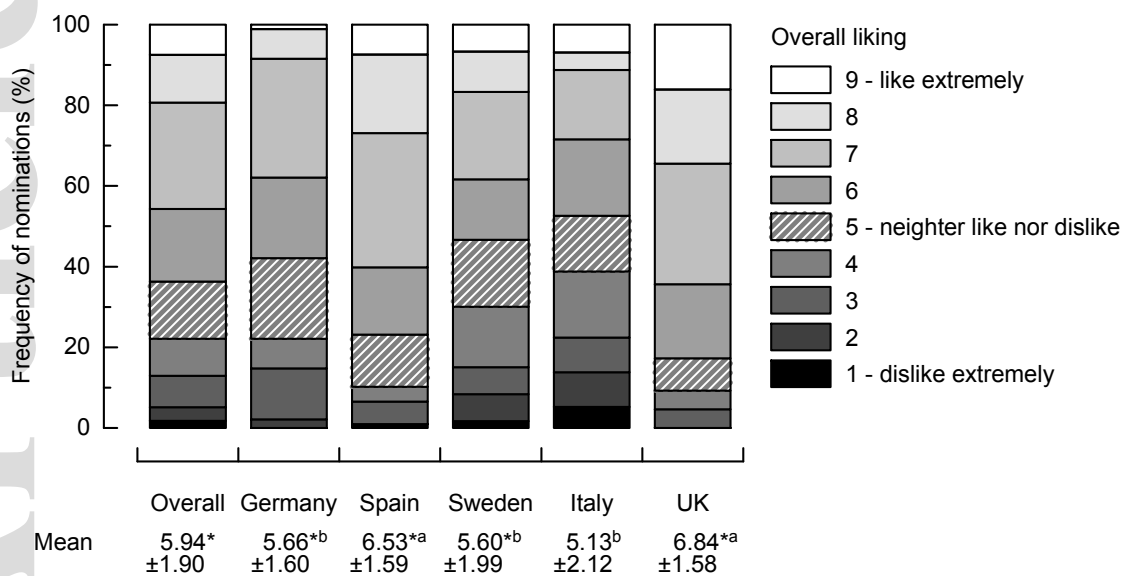


Figure 1. Overall liking of pomace crackers, depending on the origin of respondents.

Asterisks indicate a significant difference to the scale midpoint "5". Country mean values with different superscripts are significantly different ($p < 0.05$).

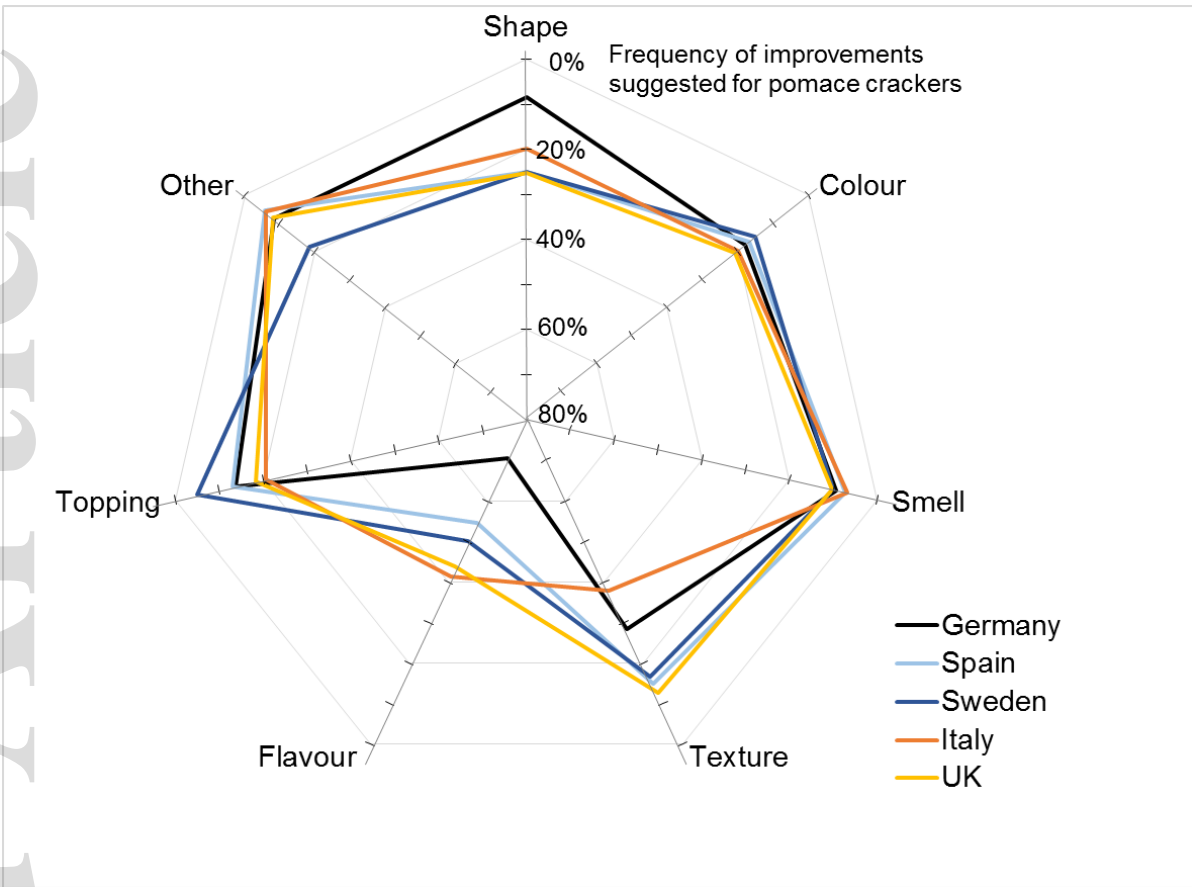


Figure 2. Nomination frequency of improvements suggested for pomace crackers, depending on the origin of respondents.

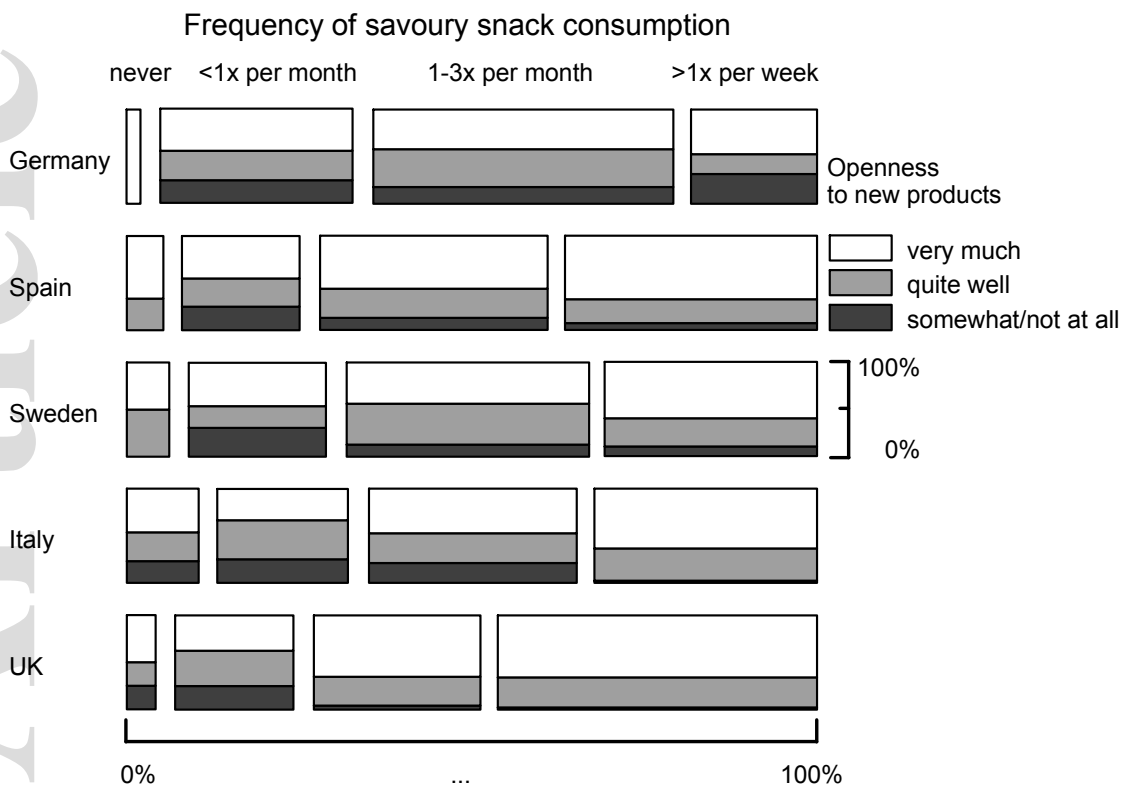


Figure 3. Marimekko diagram illustrating distributions of snack consumption frequency and its dependency on respondent country and openness to new products. Openness in each box vertically equals to 100% and the four boxes on snack consumption frequency in direction of x-axis also sum up to 100%.

Table 1. Socio-demographic information, openness to new foods and frequency of savoury snack consumption of the respondents

	Total	Germany	Spain	Sweden	Italy	UK
Count of respondents	466	95	108	60	116	87
Female (%)	47.6	42.1	56.5	33.3	49.1	50.6
Age (%)						
18 - 25 years	59.4	45.3	75.0	23.3	95.7	32.2
26 - 45 years	32.4	46.3	18.5	61.7	4.3	51.7
> 45 years	8.2	8.4	6.5	15.0	0.0	16.1
Undergoing education (%)	70.8	72.6	82.4	28.3	99.1	46.0
Openness to new foods (%)						
very much	53.0	45.3	59.3	50.0	50.0	59.8
quite well	32.4	32.6	28.7	35.0	34.5	32.2
somewhat/not at all	14.6	22.1	12.0	15.0	15.5	8.0
Frequency of savoury snack consumption (%)						
never	6.2	2.1	5.6	6.7	11.2	4.6
< 1 x per month	21.9	30.5	18.5	21.7	20.7	18.4
1 - 3 x per month	36.1	47.4	36.1	38.3	32.8	26.4
≥ 1 x per week	35.8	20.0	39.8	33.3	35.3	50.6

Table 2. Selected aspects for cracker improvement.

Aspect		Suggestion**		Frequency within aspect
Description	Frequency*	Description	Frequency*	
Shape	95 (20.4%)	Bigger	52 (11.2%)	54.7%
		Thicker	27 (5.8%)	28.4%
Colour	85 (18.2%)	Brighter / Not brown	53 (11.4%)	62.4%
Smell	40 (8.6%)	More aromatic	28 (6.0%)	70.0%
Texture	108 (23.2%)	Crispier	76 (16.3%)	70.4%
Flavour	242 (51.9%)	Saltier	105 (22.5%)	43.4%
		Spicier	26 (5.6%)	10.7%
		Less bitter	31 (6.7%)	12.8%
		Not specified	54 (11.6%)	22.3%

* $n_{total} = 466$

** Pertinent attributes (nominated by > 5% (> n = 24)) of all respondents. Proportions may overlap because of multiple answers.

Table 3. Independencies and correlations obtained from contingency tables of data collected on pomace crackers and respondents.

Compared attributes		Chi ²	df	p	Cramér's V
Overall liking	vs. Suggested improvement	48.4	6	0.000	0.322
	vs. <i>Cracker shape/size</i>	6.2	6	0.404	0.115
	vs. <i>Cracker colour</i>	12.5	6	0.053	0.163
	vs. Cracker smell	15.1	6	0.013	0.174
	vs. Cracker texture	21.0	6	0.002	0.212
	vs. Cracker flavour	65.5	6	0.000	0.375
	vs. <i>Cracker topping</i>	4.5	6	0.615	0.098
	vs. <i>Other cracker attributes</i>	1.4	6	0.974	0.051
	vs. Origin	83.5	24	0.000	0.212
	vs. Sex	18.8	6	0.005	0.201
	vs. Age	22.7	12	0.024	0.156
	vs. Occupation	14.6	6	0.024	0.177
	vs. Snack consumption frequency	30.7	18	0.031	0.148
	vs. Openness to new foods	29.5	12	0.003	0.178
	vs. <i>Pomace recycling</i>	11.0	6	0.054	0.176
Suggested improvement	vs. <i>Origin</i>	1.4	4	0.852	0.054
	vs. <i>Sex</i>	1.9	1	0.194	0.064
	vs. <i>Age</i>	0.7	2	0.706	0.039
	vs. <i>Occupation</i>	0.5	1	0.477	0.034
	vs. <i>Snack consumption frequency</i>	3.2	3	0.361	0.083
	vs. <i>Openness to new foods</i>	4.1	4	0.392	0.094
	vs. <i>Pomace recycling</i>	1.1	1	0.353	0.048
Snack consumption frequency	vs. Origin	30.6	12	0.002	0.148
	vs. <i>Sex</i>	1.6	3	0.652	0.059
	vs. <i>Age</i>	12.1	6	0.060	0.114
	vs. <i>Occupation</i>	3.5	3	0.319	0.087
	vs. Openness to new foods	20.6	6	0.002	0.149
	vs. <i>Pomace recycling</i>	4.9	3	0.180	0.102
Openness to new foods	vs. <i>Origin</i>	10.4	8	0.235	0.106
	vs. <i>Sex</i>	14.3	2	0.001	0.175
	vs. <i>Age</i>	7.7	4	0.103	0.091
	vs. <i>Occupation</i>	0.8	2	0.660	0.042
	vs. Pomace recycling	8.7	2	0.013	0.137
Pomace recycling	vs. Origin	15.1	4	0.005	0.180
	vs. <i>Sex</i>	0.4	1	0.663	0.030
	vs. <i>Age</i>	0.0	2	0.986	0.008
	vs. <i>Occupation</i>	0.5	1	0.634	0.032

bold – $p \leq 0.01$ & Cramér's V > 0.2; regular – $p \leq 0.05$; *italic* – $p > 0.05$