Individual Variation in Food Perception and Implication in Consumer Preference of Sustainable Products

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This PhD thesis focused on the determinants of liking of novel plant-based food formulations added with innovative ingredients, exploring individual variation in consumer perception and preference to foster the transition to a healthy and sustainable diet. Sensory data were combined with technological and instrumental ones to develop innovative improved foods. In addition, a cross-national study was performed to better understand possible cross-national differences in consumer acceptance of new food formulations added with micro- and macroalgae.

Variazione individuale nella percezione del cibo e implicazioni sulla preferenza del consumatore per prodotti sostenibili

Questa tesi di dottorato si è focalizzata sulle determinanti del gradimento di formulazioni alimentari a base vegetale arricchite con ingredienti innovativi, esplorando la variazione individuale nella percezione e preferenza del consumatore per favorire la transizione verso una dieta sana e sostenibile. I dati sensoriali sono stati associati a dati tecnologici e strumentali per sviluppare alimenti innovativi migliorati dal punto di vista nutrizionale e sensoriale. Inoltre, è stato previsto uno studio cross-nazionale per meglio comprendere le possibili differenze di gradimento del consumatore guidate dal paese di origine per nuove formulazioni alimentari con aggiunta di micro- e macroalghe.

**Key words**: Sensory science, Consumer science, pulses, pseudocereals, algae.

# **1. Introduction**

Current food systems are no longer sustainable. By contributing to climate change, freshwater use and biodiversity loss, food production is a major driver of global environmental change (Willet et al. 2019). Therefore, ensuring healthy food systems requires sustainable transformation of the entire food chain. In this context, the exploitation and use of minor crops, the replacement of animal proteins with those of vegetable origin, as well as the use of innovative ingredients are important strategies to increasing environmental sustainability. Among minor crops, Tartary buckwheat (*Fagopyrumtataricum Gaertn*.) is a pseudocereal that has environmental (Giupponi et al. 2019) and nutritional benefits (Ahmed et al 2014) but reduced appreciation for its bitter and astringent properties which can limit its consumption (Suzuki et al. 2004). On the other hand, pulses represent a particularly promising alternative protein source with excellent nutritional properties and require fewer natural resources than traditional crops (Nemecek et al. 2008; Preissel et al. 2015). Finally, the introduction of ingredients not belonging to the culinary culture of Western countries could contribute to the diversification in the development of new healthy and sustainable products. In this context, micro and macro algae have received particular attention in recent years, both for their ability to grow in extreme conditions (Caporgno & Mathys, 2018) and for their important nutritional profile (Khan et al., 2018; Wells et al., 2017). However, algae have some sensory characteristics (green-blue color and fishy taste and smell) that are disliked by consumers.

This PhD project contributed to the sensory optimization of sustainable plant based products with high nutritional value through the study of consumers liking and expectations in order to find drivers of acceptance and/or rejection.

The present PhD project consists of three main activities, two of which (A1 and A2) are part of the MIND FoodS Hub project (Lombardy Region):

A1) Study of Tartary buckwheat exploitation as an ingredient in food formulations to verify whether it is associated with the perception of unpleasant sensory characteristics (e.g. bitter and astringency) and explore its drivers of liking and rejection.

A.2) Study of the effect of health and environmental information on liking and expectations of consumers with different level of food neophobia for food formulations added with pulses (red lentils and chickpeas).

A.3) Study of cross-national differences in the acceptability as well as drivers of liking and rejection of crackers added with different micro- and macro-algae in children and adults (activity in progress).

# **2. Materials and Methods**

A.1) Six gluten-free samples of a corn-based formulation were produced, added with 20%, 30% or 40% of either common buckwheat (CB) or Tartary buckwheat (TB) flour (Raetia Biodiversità Alpine, Teglio, Sondrio, Italy). Sensory profiling data (8 trained assessors) were related to various instrumental analyses: electronic tongue, colorimeter CIELAB and Texture Analyzer. Subsequently, the overall liking and appropriateness of the sensory characteristics were assessed to explore drivers of liking and rejection involving 120 consumers.

A.2) Whole-corn flour (Molino Filippini S.r.l., Teglio, Sondrio, Italy) was used to prepare one control sample (100% whole corn) and two experimental samples replaced with 20% pulse flour (either chickpea or red lentil). One hundred- twenty seven consumers assessed samples overall liking in blind (tasting without information), expected (only information without tasting) and informed conditions (tasting with information) to study the effect of information on consumer expectations. To explore the effect of information on consumer clusters, questionnaires on food neophobia (fear to try new foods) and sustainable behaviour were provided.

A.3) A control sample (100% wheat) and five experimental samples with the addition of 5 % (w/w) of *Arthrospira platensis* (Green Spirulina, entire bacterium), *Arthrospira platensis* (Blue Spirulina, fractionated protein), *Palmaria palmata*, *Saccharina latissima*, or *Lithothamnium calcareum* were developed. The overall liking of the six samples, their sensory description using Check-All-That-Apply (CATA) questionnaire as well as the identification of the preferred sample were envisaged with 321 adult consumers to determine the drivers of liking and rejection and to establish which micro or macro algae were most suitable to enrich the cracker samples.

# **3. Results and Discussion**

A.1) Sensory profiling data, partially supported by instrumental analyses (Fig. 1), revealed a higher intensity of bitterness, astringency and a darker colour in samples with high percentages of Tartary buckwheat (TB30; TB40). These properties may justify overall liking data (Fig.2) showing that samples, although well accepted, differed significantly in terms of acceptance (F 5,694=6.40, p<0.0001), with TB40 being the only one to receive lower hedonic ratings. In particular, high intensity of colour, overall flavour, bitterness and texture were identified as drivers of disliking according to PLSR analysis (Fig.3). These findings confirm that polyphenols present in buckwheat may impart astringency and bitter taste (Soares et al., 2013) as well as influence colour (Khoo et al., 2017). However, results showed that by keeping Tartary buckwheat concentration <40%, new sustainable and accepted products can be developed. Moreover, cluster analyses conducted on overall liking (results not shown), identified a non-negligible percentage of consumers (30%) who prefer the samples with the highest Tartary buckwheat additions, suggesting that there is a possible target of consumers willing to accept these products.



A.2) One-way ANOVA showed that samples within each experimental condition were comparable (Tab. 1) indicating no effect of type of flour on liking; overall, the samples were well accepted, with mean liking scores above the middle of the scale setted at 50. Moreover, for all samples, there was a disconfirmation of expectation (E$-$B >0), this means that consumers rated the products worse than their expectations (Tab. 1). This disconfirmation was associated with an assimilation effect (R$-$B >0) for both samples containing pulses. This result suggests that the conveyed health and environmental information influenced liking, leading consumers to change their hedonic score in the direction of their expectations. However, this assimilation was incomplete (R$-$E <0). These results are consistent with previous research showing that information about health (Saba et al., 2010) and sustainability (Laureati et al., 2013) may lead to increased consumer expectations and liking but sensory properties play a major role.

**Table 1.** *Mean hedonic scores under the 3 experimental conditions (B = blind; E = Expected; R = Real) and expectation effect on samples liking (n.s., not significant; \*, p<0.05; \*\*, p<0.01; \*\*\*, p<0.001) Disconf. = negative disconfirmation, Ass. = assimilation. (1) Comparison by column (samples within B,E or R condition) are based on 1-way ANOVA; (2) Comparison by row (conditions within samples) are based on paired t-test.*

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The same information affected differently consumers hedonic responses according to their food neophobia index (Tab. 2). A negative disconfirmation of expectation (E$-$B >0) was found only for Neophilic and Neutral groups. This disconfirmation was associated with a complete assimilation effect for the red lentil sample for Neophilic people and for chickpea sample for Neutral ones, while incomplete assimilation was found for red lentil sample for Neutral subjects. No significant differences between blind and expected conditions were found for the Neophobic group (Tab. 2). This result can be attributed to the fact that neophobic people are individuals with low reactivity towards novel food products (Tuorila and Hartmann, 2020) and more generally, have little interest in food (Jaeger et al., 2017), even when such food is accompanied by positive information.

**Table 2.** *Mean hedonic scores provided by Neophilic, Neutral and Neophobic consumers scores under the 3 experimental conditions (B = blind; E = Expected; R = Real) and expectation effect on samples liking (n.s., not significant; \*, p<0.05; \*\*, p<0.01; \*\*\*, p<0.001) Disconf. = negative disconfirmation, Ass. = assimilation.*



A.3) Two-way ANOVA revealed that respondents across all countries provided on average positive liking scores towards all the algae enriched crackers, with Italian respondents providing significantly higher liking scores compared to Belgium and Sweden (FSample =24.2; *p*<0.0001; FCountry = 14.8; *p*<0.0001; FSample\*Country =7.7; *p*= *p*<0.0001) (Fig. 4). These results are supported by previous work in the literature that has established that food preferences differ between countries (Baharuddin et al., 2015). Moreover, Principal Coordinate Analysis revealed that, for all countries, characteristics such as “toasted bread flavor”, “salty” and “crunchy” had positive impact on liking. For Belgium and Sweden rejection drivers were related to “off-flavor”, while for Italy to “hard texture” and “speckled appearance“. For Italy, “green color“ was a driver of acceptance (Fig. 5). The same products are currently being tested with children from different EU countries.



***Figure 4*.** *Mean liking scores for the control samples and the crackers enriched with algae in each country. Different letters indicate significant differences (p< 0.0001).*



***Figure 5.*** *Symmetric plot derives from Principal Coordinate Analysis (PCA) based on CATA description of 6 crackers for the whole sample of a) Belgian, b) Italian and c) Swedish consumers (n=321).*

# **4. Conclusions and Future Perspectives**

This PhD project, through 3 main studies, has contributed to a better understanding of the factors involved in consumer acceptability of new food formulations added with sustainable and innovative ingredients. The outcome of this PhD project represent an effective contribution to food companies interested in developing new healthy and sustainable products. The results obtained show that: A.1) Tartary buckwheat can be added to corn-based gluten-freeformulations in concentrations up to 30% without compromising consumer acceptance. However, it is suggested to add this pseudocereal also to more widely consumed products than the one used in our study. A.2) Associating new sustainable ingredients with beneficial health and environmental information can be a strategy to improve consumer liking and expectation potentially contributing to promote their consumption. However, health and environmental information is completely ineffective for individuals with a higher food neophobia level. This indicates the need to consider consumers’ individual characteristics and to develop appropriate and personalized communication strategies when specific innovations are launched on the market. A.3) The addition of micro- and macro-algae in crackers seems promising, however, country of origin has a significant effect on liking. Data on children from the same European countries is being collected to investigate the acceptability as well as drivers of liking and rejection of crackers added with micro- and macro-algae in another population’s segment.

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