Consumers' attitudes towards novel recycling strategies of food by-products: the influence of food technology neophobia and information

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Abstract

The recycling of food by-products into new functional foods can be very challenging, since the manufacture of novel foods often requires unconventional food technologies. Moreover, there is considerable evidence that consumers are wary of both novel foods and technologies because of the perceived risks and a perceived lack of health benefits. The aim of the present study was to investigate consumers' attitude towards uses of food by-products in developing foods with selected functionalities.

Results suggested that education and, most of all food technology neophobia and information, are critical factors in facilitating the widespread adoption of new food technologies. Moreover, positive attitudes towards food by-products were found, even in people characterized by a greater food neophobia and lower education level. These positive attitudes could be considered a starting point for the food industry to promote the design of novel recycling strategies of food by-products in the perspective of the circular economy.

Keywords: food neophobia; novel foods; consumers' attitude; food by-products; sustainability; circular economy;

Introduction

Nowadays, the highly competitive market forces companies to develop sustainable foods using novel technologies as a strategy to succeed. However, consumers' attitude of new technologies determines its success or failure in the marketplace. In this context, there are two major consumers' tendencies: on one hand, there is a growing demand for innovation (functional foods and healthy foods), and on the other hand there is a rising request for a return to the naturalness and purity of foods (organic foods and natural foods) (Giordano et al., 2017). Even though industry needs using innovative technologies in food development, there is large evidence that a major group of

consumers are wary of both novel foods and technologies because of the perceived risks and lack of health benefits (Zhang and Liu, 2015; Frewer et al., 2011; Cox et al., 2007; Tucker et al., 2006;). In particular, the manufacture of novel foods often requires unconventional food technologies since some constituents need to be added, removed or modified. This means that these products could be perceived as less natural than traditional products (Frewer et al., 2003; Knight et al., 2008).

The prospect of recovering high added-value compounds from these materials has promoted various research projects, however, only a few have come to a commercial implementation (Galanakis, 2015). Food by-products are of particular interest for the production of novel ingredients, based on the content of functional constituents, such as dietary fibre and polyphenols (Laureati et al., 2017). Recovery of target bioactive compounds from food waste could require new and emerging technologies such as solvent extraction and nano-encapsulation (Lavelli et al., 2017). Alternatively, microorganisms or fungi could be applied to colonize, degrade and convert food waste into a biomass rich in target bioactive compounds (Diaz et al., 2011; Lavelli et al., 2018). Hence, the recycling of food by-products into new functional foods can be very challenging compared to the foods that conventionally have a high healthy image. Moreover, information's role conveyed by labelling or public participation, is crucial because consumers cannot perceive the benefit of novel technologies and foods directly from the product, unlike for instance taste and other sensory characteristics (Kim and Kwak, 2015; Arvanitoyannis and Krystallis, 2005; Eiser et al., 2002). Thus, insufficient or contradictory knowledge contribute to the ambivalence that characterizes public responses to new foods.

In order to investigate consumers' attitude and intentions towards new foods, various analytical instruments and psychometric scales have been proposed (e.g. Cox et al., 2007, Eiser et al., 2002). Among them, Cox and Evans (2008) developed the Food Technology Neophobia Scale (FTNS), which has been indicated as a valid tool for assessing consumer fears towards food technologies because of its specific focus on technology rather than food (Matin et al., 2012; Evans et al., 2010). Data in literature has showed that FTNS is suitable to predict consumer behavioural responses to

food involving the adoption of mature technologies, such as genetic modification, nanotechnology, modified atmosphere packaging or fortified foods (Chen, 2018; Vidigal et al., 2015; Verneau et al., 2014). Although the relationship between the attitudes of consumers to novel foods and technologies has been shown in literature (see Giordano et al., 2017, for a review), actually what is lacking is research on the relationship between attitudes towards the new food by-products used in food production. Investigating consumers' attitude towards food by-products is particularly important for those food chain side-streams that are receiving attention as potential sources of healthy food ingredients, such as winemaking by-products. Indeed, winemaking by-products are usually handled with no or low profit, such as disposal into the soil or incineration or use for animal feed production. Conversely, if properly recovered, winemaking by-products could be recycled in various added-value food applications (Lavelli et al., 2017).

In this context, the aim of the present study was to investigate how food technology neophobia level, socio-economic variables and information about novel foods and technologies may affect consumers' attitude towards uses of food by-products in developing foods with selected functionalities.

Material and Methods

Participants

During the XV edition of BergamoScienza, which took place in Bergamo (Italy) from 2nd to 15th October 2017, a total of 309 participants were randomly selected and interviewed through an interviewer-administered questionnaire. Participants were randomly put into two groups: 'Informed' group (n=165) in which subjects were informed about exemplifying uses of by-products in food formulation before answering the questionnaire, and the 'Not Informed' group (n=144) in which the subjects were not. Of the 309 interviewed participants 36 failed to complete the survey, giving a final sample of 273 subjects of whom n=148 belonged to 'Informed' group and n=125 belonged to 'Not Informed' group.

The average age of subjects was 43.9±12.7 (range from 18 to 72), 46.1% were male and 53.9% female. In four age groups (30 years or under, 31–44 years, 45–54 years and 55 years or over) there were 19.9%, 27.8%, 31.1%, 21.2% of the respondents, respectively. A total of 47.2% of participants had completed college (undergraduate or graduated degree), and 3.3% had a PhD degree.

Food prototypes

The role information has been assessed providing to the 'Informed' group some food prototypes added with winemaking by-products, without permission to taste them, and their awareness was raised regarding the benefits and the concerns towards by-products, as detailed in Table 1. For prototype preparation, white and red grape pomace were recovered from vineries and processed into dried micronized grape skins (GS) and maltodextrin-encapsulated phenolic extract (eGSP) as detailed previously (Lavelli et al., 2017). The following food prototypes were prepared: bread added with 10% GS and tomato puree added with 3% GS (Lavelli et al., 2016a), apple puree added with eGSP (Lavelli et al., 2016b); cheese added with 0.8 % GS (Marchiani et al., 2016a) and yogurt added with 6% white and red GS (Marchiani et al., 2016b).

[PLEASE INSERT TABLE 1]

Survey

The survey was structured into three sections: the first section of the questionnaire collected socio-demographic information (age, gender and educational level) on the interviewed. The second section attempted to assess the subjects' attitudes towards food technology, using the 13 statements constituting the FTNS scale of Cox and Evans (2008) translated in Italian. Finally, a statement about attitude towards positive effects on health and environment of food by-products reutilization

129 was provided ('In the development of novel foods, the reutilization of food by-products (e.g. seeds,
130 peels etc.) can have positive effects on environment and consumers' health').
131 For all the statements, subjects were asked to express their opinion using a Likert 7-point
132 agree/disagree scale anchored 'strongly disagree' (1) to 'strongly agree' (7).
133
134 **Statistical analysis**
135 To confirm the validity of the Italian version of the FTNS, responses of the participants to the 13
136 statements were subjected to Principal Components Analysis (PCA) with Promax rotation and
137 calculation of Cronbach's alpha. A good internal consistency was assumed when the Cronbach's
138 alpha was greater than the suggested value of 0.70 (Nunnally and Bernstein, 1998). Factorability of
139 the sample was tested by the Kaisere-Meyere-Olkin Index and by Bartlett's sphericity test. The
140 Kaisere-Meyere-Olkin index was considered suitable for factor analysis when greater than 0.50
141 (Verbeke and Viaene, 1999). The Bartlett's sphericity test should be significant ($p < 0.05$) for
142 considering suitable the factor analysis (Verbeke and Viaene, 1999).
143 Individuals' classification based on their food neophobia technology is obtained by summing the
144 individual values for each item, after the neophilic items had been reversed. Thus, the scores
145 theoretically ranged from 13 to 91 and the highest value represents the individuals characterized by
146 a greater neophobia (Cox and Evans, 2008).
147 Two-way Analysis of variance (ANOVA) was performed to examine Food technology neophobia,
148 considering 'Gender' (Male vs Female), 'Age' (30 years or under, 31–44 years, 45–54 years and 55
149 years or over), 'Education level' (High vs Low) and their two-way interactions as main factors.
150 Subjects were divided into three Food technology neophobia groups: 'Neophilics' (16% of the total
151 consumers sample) characterized by low food technology neophobia scores (13.0-30.5), 'Neutrals'
152 (67% of the total consumers sample) characterized by medium food technology neophobia scores
153 (30.6-57.9) and 'Neophobics' (17% of the total consumers sample) characterized by high food
154 technology neophobia scores (58.0-91.0). The participants' neophobia level range was defined from

the average of the FTNS (44.2) ± one standard deviation (13.7). This type of classification was used in earlier studies (Jeżewska-Zychowicz and Królak, 2015; Vidigal et al., 2015; Choe and Cho, 2011; Tuorila et al., 2011; Olabi et al., 2009) and was considered a validated method. Furthermore, the two-way ANOVA was performed to examine consumers' attitude towards by-products, considering 'Education level' (High *vs* Low), 'Food technology neophobia' (Neophilics, Neutrals, Neophobics) and 'Information' (Informed *vs* Not informed groups) and their two-way interactions as main factors. When a significant difference ($p<0.05$) was found, least significant difference (LSD) *post hoc* test was used.

All the analyses were performed using IBM SPSS Statistics for Windows, Version 24.0 (IBM Corp., Armonk NY).

Results

Neophobia in relation to food technology

A factorial analysis of the participant responses to the 13 statements was performed to confirm the validity of the Italian version of the FTNS. Results of the Kaisere-Meyere-Olkin test (KMO=0.883) and Bartlett's sphericity test (χ^2= 1391.03, $p<0.001$) showed adequacy of the sample for factorial analysis. Cronbach's alpha of the 13-item scale is 0.86, indicating good internal reliability.

The Principal Components Analysis with Promax rotation explained 60.1% of total variation in the data. Details of the 13 statements, factor loadings and variance explained by each component are given in Table 2.

[PLEASE INSERT TABLE 2]

The first component explained 41.3% of the total variance, related to consumers' perception of new food technologies and their risks and summarized items describing negative attitudes towards new food technologies or new foods (items 1, 2, 3, 4, 5, 9, 10, 11 and 12). The second component, which explained 11.3% of total variance, was positively correlated with items that describe new food technologies as being healthier choices (items 6, 7, 8). The third component (7.5% of total variation) was related to the confidence in the role of the media (item 13).

General attitudes towards food technology and how its benefits and risks are perceived was investigated by means (± SD) of the 13 psychometric items of the FTNS, as shown in Table 2.

The mean level of agreement stated on a scale from 1 to 7 showed a prevailing widespread sense of uncertainty on the effects of technology (item 3: M= 3.5 ±1.7; item 10: M= 3.7 ± 1.7), especially on long term health effects (item 6: M= 3.8 ±1.5), combined with a low level of confidence in the role of the media (item 13: M= 4.4 ±1.9).

The average score of neophobia in relation to food technology by the sample of Italian respondents was 44.2 (±13.7). Sum of the individual values obtained for each item provided by the participants ranged from 13.0 to 87.0.

There was a significant effect of education level ($p< 0.05$) on FTNS scores, where participants with higher education levels also presented lower neophobia (42.3 ±12.4) compared with participants with lower education levels (46.1±13.2). The main effects 'Gender' and 'Age' and all the interactions were not significant.

Consumers' attitude towards positive effects on health and environment of food by-products reutilization

Results from two-way ANOVA showed a significant effect of the main factors 'Education level' ($F_{(1, 263)}= 6.25$; $p< 0.05$), 'Food technology neophobia' ($F_{(2, 263)}= 5.90$; $p< 0.01$) and 'Information' ($F_{(1, 263)}= 25.88$; $p< 0.001$) on consumers' attitude towards food by-products reutilization.

According to the *post hoc* test, as shown in Figure 1a, 'Neophilics' gave significantly higher attitude scores compared to 'Neutrals' ($p < 0.05$) and 'Neophobics' ($p < 0.01$), who gave scores comparable to each other. Respondents characterized by low schooling and information levels (Figure 1b-c) gave significantly lower attitude scores compared to those given by subjects with high education level and information ($p < 0.05$ and $p < 0.001$, respectively).

[PLEASE INSERT FIGURE 1a-c]

The interaction 'Information' * 'Education level' and 'Information' * 'Food technology neophobia' were significant ($F_{(1, 263)} = 5.10$, $p < 0.05$; $F_{(2, 263)} = 4.04$, $p < 0.05$, respectively). The interaction 'Education level' * 'Food technology neophobia' was not significant.

According to the *post hoc* test, the effect of information was observed in subjects with high level of education, 'Neophilics' and 'Neutrals' ($p < 0.05$) and had a greater impact for subjects with low level of education and 'Neophobics' ($p < 0.001$) (Figure 2a-b).

[PLEASE INSERT FIGURE 2a-b]

Discussion

In the present study, we investigated how food technology neophobia level, education level and information about novel foods and technologies may affect consumers' attitude towards uses of food by-products in developing foods with selected functionalities.

FTNS demonstrated to be a reliable and valid instrument for predicting individuals' willingness to approach foods produced using novel technologies even when translated in Italian. Results from the PCA reinforced this assumption, since the second and third principal components separated reversed from unreversed items, demonstrating the ability of the scale to measure the distinctive dimensions which describe consumers' reactions to novel food technology. Indeed, comparing the results of the analysis with those carried out by Cox & Evans (2008) very close conceptually results were observed. The first component, which explained 41.3% of the total variance, was highly correlated to the statements 1-5 and 9-12 and combined together the items of two components originally labelled as "New food technologies are unnecessary" and "Perception of risks" (Cox and Evans, 2008). The second component (11.3 % of the total variance explained), correlated to the statements 6-8 and corresponded to the items originally defined as "Healthy choice". Finally, the third component (7.5% of the total variance explained) was strongly associated only to the statement 13 and matches the item originally labelled as "Information/media".

The higher mean values of items 3, 6, 10 and 13 revealed a prevailing widespread sense of uncertainty about new food technologies, higher levels of concern for the potential impact on health and a general mistrust about the quality of media information.

By comparing the average scores of food technology neophobia in this sample of Italian respondents (M= 44.2 ±13.7) with those evaluated from other studies in Italy and other countries, it was found that northern Italian consumers present a comparable level of fear of food technologies to Brazilians respondents (M= 47.0 ±12.0) (Vidigal et al., 2015) and Australians (M= 53.6 ±11.3) (Evans et al., 2010) and lower level of fear than southern Italian (M=60.9 ±11.3) (Verneau et al., 2014) and Canadians (M= 58.5 ±6.2) (Matin et al., 2012). These differences could be due to the urban context in which survey was carried out.

Neophobia in relation to food technology was slightly but significantly influenced by education level. According to previous studies (Vidigal et al., 2015; Evans et al., 2010), people with higher degrees of education seem to be more open to new products and new technologies. Thus, it

becomes necessary to increase the knowledge of consumers to reduce neophobia, since it is well known to have a positive impact on food acceptance.

FTNS resulted to be a good predictor of acceptance of food by-products, since the average consumers' scores increased from 5.8 for the 'Neophobics' to 6.5 for the 'Neophilics'. In the present study attitudes towards food by-products were investigated for the first time and found to obtain relatively high scores, even if the uses of food by-products exemplified were not familiar to consumers, given that none of them has already been approved by the current regulation. This is an interesting result and could be considered a starting point for the reutilization of food by-products in novel food formulations, since also people characterized by a greater food neophobia seem to be generally opened to food by-products that provide some health benefit. In a previous study, bioactive proteins were also found to be positively accepted by neophobic subjects, who gave a score of 5.0 in a 7-point scale, while neophilics gave 6.5 (Vidigal et al., 2015). Conversely, rating for use of genetic-modified (GM) foods and nanotechnologies were much lower, 5.0 and 5.7 in neophilics and 2.8 and 3.1 in neophobics, respectively (Vidigal et al., 2015).

Besides food technology neophobia, the level of information provided and, to a lesser extent, the education level influenced consumers' attitude towards reuses of food by-products. Consumers' confidence in information and interest in food production information is critical in terms of consumers' acceptance (Laureati et al., 2016; Laureati et al., 2013; Villegas et al., 2008). The results of this study showed that consumer appreciated receiving information that may facilitate their purchase decision related to foods produced with new technologies, since this seems to increase their confidence in foods. Indeed, it has been shown that a lack of communication/information among consumers regarding the benefits and the concerns towards food by-products can serve as a major barrier to their acceptance. Thus, the educational institution and, most of all, food industry should invest in education campaigns and communication programs to increase consumer confidence regarding healthy and sustainable characteristics of food by-

products, in order to have a positive impact on consumer behaviours, especially on those characterized by a greater reluctance or a lower education level.

Some study limitations should be mentioned. Since our sample was mainly collected within an urban area in northern Italy and during a specific event, future work could involve a larger sample size with experiments conducted in various geographical areas. Further studies are needed to ensure that the positive attitude towards food by-products has sufficient impact to enable consumers' choices of by-products enriched foods, which generally have a modified sensory profile with respect to conventional foods.

Conclusion

In conclusion, FTNS was a valuable tool for predicting the driving force behind consumer attitudes towards food by-products that have potential health benefits and are produced in the perspective of sustainable processing. Results underline that education and, most of all food technology neophobia and information are critical factors in facilitating the widespread adoption of new food technologies and avoid innovation failure in marketing strategies. The attitude scores for 'Informed' consumers were close to the upper value of the rating scale, thus indicating that they were open to food by-product reutilization in processing of novel foods. This could be a starting point for the food industry in order to promote the design of novel recycling strategies of food by-products.

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The author contributions were as follows: CC, VL, EP designed the study. CC, CP and VL carried out the experiment and CC performed the statistical analysis. CC, VL, CP and ML wrote the manuscript. VL, EP, CC, CP and ML regularly discussed the experiments, analyzed the results, and provided useful suggestion during the project. All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that they do not have any conflict of interest.

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423 **Table 1.** Prototypes shown and information provided to the 'Informed' group.

Prototypes	Benefits	Concerns
1. Bread added with red/white micronized grape skins 2. Tomato puree added with micronized white grape skins 3. Apple puree added with red grape skins extract 4. Cheese added with red/white grape skins 5. Yogurt added with red /white grape skins	Improved handling of waste, i.e., decrease in the accumulation of polluttant organic matter (all prototypes) Increase in the income for winemakers (all prototypes) Increase in the intake of dietary fibre, i.e. potential to decrease cardiovascular disease (all prototypes) Increase in the intake of antioxidants, i.e., potential to balance the oxydative stress (all prototypes) Intake of inhibitors of glucose release, i.e. potential to decrease hyperglycaemia damage (prototypes 1, 2) Replacement of synthetic colorants (prototype 3)	Need for effective dehydration and storage technologies for grape skins to prevent contamination (microorganisms, mycotoxins) Need to optimize processing technologies in order to prevent the inhibitory effect of grape skin phenolic on yeasts (in bread) and lactic acid bacteria (in yogurt and cheese) Use of fermented grape skins in food production still requires authorization by the European Food Safety Authority Lack of specific regulamentation could result in incorrect labelling regarding health benefits

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426 **Table 2.** Italian and English version of the Food Technology Neophobia Scale: variance explained, factor loadings, items mean and standard
427 deviation (SD). Items scores on a Likert 7-point agree/disagree scale (1=strongly disagree; 7= strongly agree).

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Item	English	Italian	Loadings			
			PC1(41.3%)	PC2(11.3%)	PC3(7.5%)	Mean (SD)
1	New food technologies are something I am uncertain about	Ho dei dubbi riguardo le nuove tecnologie alimentari	**0.73**	0.05	-0.03	3.2 (1.6)
2	New foods are not healthier than traditional foods	I nuovi alimenti non credo possano essere considerati più sani di quelli tradizionali	**0.85**	-0.19	0.22	3.4(1.8)
3	The benefits of new food technologies are often grossly overstated	I vantaggi delle nuove tecnologie alimentari sono spesso sopravvalutati	**0.64**	0.11	-0.15	3.5(1.7)
4	There are plenty of tasty foods around so we do not need to use new food technologies to produce more	Esistono già molti alimenti gustosi, non c'è bisogno di utilizzare nuove tecnologie alimentari per produrne di più!	**0.70**	-0.04	-0.16	3.2(1.9)
5	New food technologies decrease the natural quality of food	Le nuove tecnologie alimentari riducono la naturale qualità degli alimenti	**0.75**	-0.02	-0.15	3.2(1.8)
6	New food technologies are unlikely to have long term negative health effects (**R**)[a]	Penso sia improbabile che, nel lungo periodo, le nuove tecnologie alimentari abbiano effetti negativi sulla salute (**R**)	-0.05	**0.72**	-0.36	3.8(1.5)

7	New food technologies give people more control over their food choices (**R**)	Le nuove tecnologie alimentari consentono alle persone di controllare maggiormente le loro scelte alimentari (**R**)	0.02	**0.80**	0.21	3.4(1.7)
8	New products using new food technologies can help people have a balanced diet (**R**)	Gli alimenti prodotti utilizzando nuove tecnologie possono aiutare le persone ad avere una dieta equilibrata (**R**)	0.05	**0.79**	0.17	3.2(1.6)
9	New food technologies may have long term negative environmental effects	Le nuove tecnologie alimentari, nel lungo periodo, penso che possano avere effetti negativi sull'ambiente	**0.73**	0.10	-0.01	3.1(1.6)
10	It can be risky to switch to new food technologies too quickly	Passare troppo velocemente a nuove tecnologie alimentari potrebbe essere rischioso	**0.73**	-0.04	0.09	3.7(1.7)
11	Society should not depend heavily on technologies to solve its food problems	La società non dovrebbe dipendere troppo dalle tecnologie per risolvere i suoi problemi alimentari	**0.66**	0.11	0.12	3.1(1.7)
12	There is no sense trying out high-tech food products because the ones I eat are already good enough	Esistono già molti alimenti gustosi, non c'è bisogno di utilizzare nuove tecnologie alimentari per produrne di più!	**0.73**	0.04	-0.05	3.0(1.8)
13	The media usually provides a balanced and unbiased view of new food technologies (**R**)	I media, solitamente, forniscono una visione imparziale e veritiera delle nuove tecnologie alimentari (**R**)	-0.07	0.08	**0.86**	4.4(1.9)

Figure Legends.

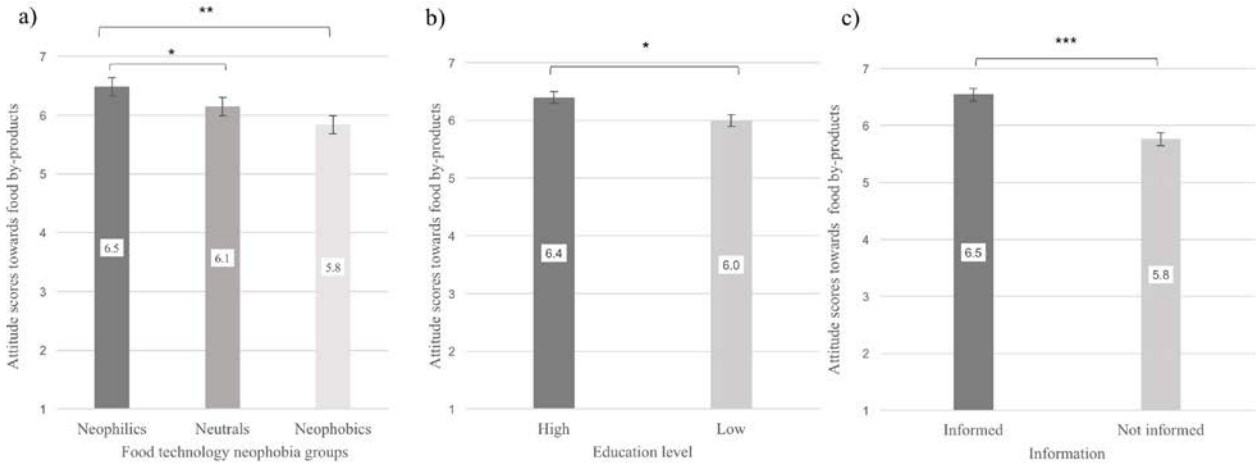

Figure 1 a-c. Consumers attitude scores ± SEM in relation to Food technology neophobia groups (a), Education level (b) and Information (c). * P< 0.05; ** P< 0.01; *** P< 0.001.

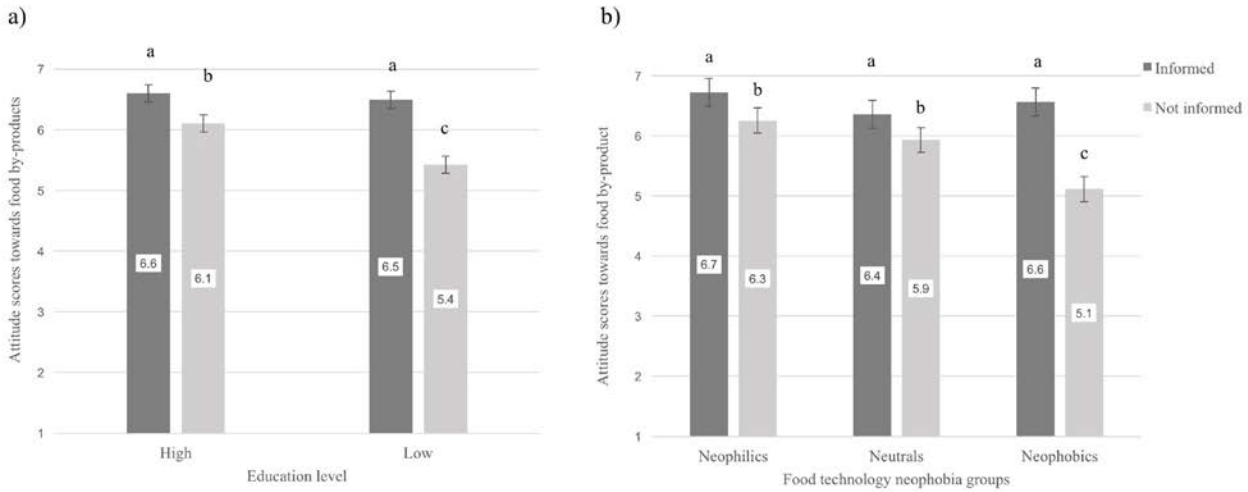

Figure 2 a-b. Consumers attitude scores ± SEM in relation to education (a) and food technology neophobia (b) levels in 'Informed' and 'Not informed' group. Different letters indicate significant differences according to *post hoc* test.