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Consumer Acceptance of Pesticide-Free Dairy Products in Germany: A Partial Least Square Model

Marie-Catherine Wendt, and Ramona Weinrich

University of Hohenheim, Germany

*Correspondence: Marie-Catherine Wendt, mariecatherine.wendt@uni-hohenheim.de

Abstract: A key challenge in this century is to ensure safe food for a growing global population while limiting environmental impacts and addressing climate change. Although pesticides ensure high yields, there are downsides to their intensive use, including negative effects on the environment, such as water, soil, and air contamination, as well as on biodiversity. To promote a sustainability transition, innovative farming systems that do not require the use of pesticides yet are non-organic can be part of the solution. To explore the attitudes toward a pesticide-free, but non-organic farming system, we examined attitudes and factors that drive German consumers to accept pesticide-free food products, using an online questionnaire to survey 1,010 German consumers. A range of hypotheses were evaluated to determine the factors that influence consumer decisions. Partial least squares structural equation modelling (PLS-SEM) served to assess consumer attitudes and acceptance of pesticide-free milk, butter, and cheese. The study results show that attitudes and acceptance for pesticide-free food products are driven by health consciousness, chemophobia, and perceived consumer effectiveness; they are inhibited by price sensitivity. We find attitudes towards pesticide-free food products to positively moderate the effect of health consciousness, while chemophobic attitudes and perceived consumer effectiveness positively moderate acceptance of pesticide-free food products. Our findings can support researchers, food industry professionals, and regulatory leaders seeking scalable pesticide-free agricultural production methods.

Keywords: Consumer Acceptance, Structural Equation Modelling, Pesticide-Free Farming, Pesticide Residues

1 Introduction

Agricultural systems are significantly linked with a number of sustainability challenges, such as biodiversity loss, climate change, and the provision of safe food for a growing world population (Godfray et al., 2010; Tudi et al., 2021). Ensuring a safe and healthy diet for a growing world population while restricting environmental impact and managing climate change is one of the greatest challenges of this century (Godfray et al., 2010; Mack et al., 2023). Thus, transforming agriculture toward more sustainable, resilient, and at the same time innovative and productive production methods is a crucial policy goal in the UN's Sustainable Development Goals (UN, 2015). In this context, political and social pressure is increasingly pushing for innovative farming systems that do not require the use of pesticides (Zimmermann et al., 2021).

The extensive use of pesticides in agriculture is intended to help safeguard yields and improve product quality (Popp et al., 2012). Their most important contribution is to prevent crop losses and thus significantly increase global food supply (Hedlund et al., 2019). However, many studies have highlighted the negative effects of pesticides on the environment, such as water, soil, and air contamination, as well as on biodiversity (Rockström et al., 2009; Sánchez-Bayo and Wyckhuys, 2019; Pelosi et al., 2021). Köhler and Triebskorn (2013) highlighted excessive pesticide use as a serious barrier to agricultural sustainability.

Beyond its environmental effects, pesticide use has come under consumer scrutiny. There have been previous investigations of consumer concerns regarding pesticide residues in foods (Koch et al., 2017; Nitzko et al., 2022; Simoglou and Roditakis 2022). Overall, these studies show that consumers view pesticide residues as a major threat to their own health and perceive products produced without the use of pesticides as healthier and safer. In this line, several studies indicate major health risks associated with pesticide residues in foods, including the risk of cancer, birth defects, neurological disorders, asthma, and damage to genetic information (Clementi et al., 2008; Baldi et al., 2010; Wickerham et al., 2012). Further, media reports on pesticide residues in food increase consumer concern (Koch et al., 2017). Lamichhane et al. (2016) shows that the majority of consumers assume any level of pesticide residue is a significant health risk, regardless of how it compares to the established legal maximum residue level.

One could note that we already have a farming system working without chemical pesticides: organic production. However, several studies report that a globally sufficient food supply in the future from organic farming alone is questionable (Badgley et al., 2007; Muller et al., 2017; Meemken and Qaim, 2018; Joshi and Piya, 2021). Further push for the development of sustainable solutions and innovations in farming systems comes from increasing restrictions on the approval and use of the active ingredients in pesticides, as well as rising pest resistance to current formulas (Zimmermann et al., 2021).

Out of this need, a new agricultural production system was developed. This new farming concept distinguishes itself from existing systems by the renunciation of the standard chemical crop protection used in conventional agriculture (Zimmermann et al., 2021). But the use of mineral fertilizers is not renounced as in organic farming (Möhring and Finger, 2022). Renouncing the use of pesticides while making targeted use of mineral fertilizers, this approach represents a reorientation in arable farming. However, although the system has already been introduced in public and private programs in Europe, it is not yet a regulated and established system. Thus, according to Finger (2024) a harmonized definition of what “pesticide-free” exactly means is still a key challenge and requires clear regulation both at a national and international level. Researchers highlight various advantages of this system: guaranteeing quantitatively and qualitatively sufficient and affordable food; environmentally and nature-friendly production methods; increased ecosystem services; preservation of agricultural landscapes; protection of biodiversity; prevention of pesticide residues in food; and lower adoption hurdles than organic farming for farmers (Zimmermann et al., 2021; Finger and Möhring, 2022; Jacquet et al., 2022). This pesticide-free farming system can be located between conventional and organic farming systems and offer consumers the opportunity to adapt their eating and shopping habits in the interests of sustainability.

Although this pesticide-free farming concept promises an agricultural production system, one that contributes to several sustainability goals and could significantly drive sustainability transformation, assessing consumer acceptance of the food produced presents an economically important challenge. Whether and to what extent untapped market potential can be developed for these products depends on their acceptance by consumers. Extensive consumer rejection of the new farming system would both undermine its market launch and deny the sustainability transformation an important ally. Therefore, understanding consumer perceptions and attitudes regarding food produced by this new system is of great interest (Zimmermann et al., 2021).

What do we know so far about consumer acceptance of pesticide-free food products? Previous research has determined consumer interest in disseminating information regarding pesticide residues via social media (Rutsaert et al., 2013), to assess how chemophobia affects consumer acceptance of pesticide use (Saleh et al., 2021), to capture public risk perceptions and level of knowledge of pesticide use (Koch et al., 2017; Nitzko et al., 2022), to determine consumer willingness-to-pay (WTP) for pesticide-free vegetables (Magnusson and Cranfield, 2005; Haghiri and McNamara, 2007; Bazoche et al., 2014; Edenbrandt et al., 2017; Nandi et al., 2017; Khan et al., 2018; Cai et al., 2019; Wang et al., 2022), and to investigate consumer preferences for pesticide-free product attributes (Yiridoe et al., 2005; Grebitus et al., 2018; Farías, 2020; Diaz-Siefer et al., 2022; Gatti et al., 2022) as well as consumer segmentation (Wendt and Weinrich, 2023). Most studies have primarily focused on consumer acceptance of pesticide-free fruits and vegetables, but not on animal-based products. Thus, we focused on animal products (milk, butter and cheese) where the animal was fed with pesticide-free feed.

However, factors influencing consumer acceptance of pesticide-free animal food products have not yet been the focus of consumer research. Thus, this study focuses on German consumer attitudes and acceptance of pesticide-free, but non-organic animal food products (milk, butter, and cheese) using a maximal representative sample of the German population. This study contributes to the existing literature by providing new evidence of consumer readiness for a cleaner agricultural production system. Using a partial least squares structural equation modelling (PLS-SEM) approach, we address the following research question:

Which factors influence German consumer attitudes and acceptance of pesticide-free, but non-organic animal food products?

The paper is structured as follows: in the next section, we develop hypotheses from a literature review followed by a description of material and methods used to conduct the PLS-SEM study. We then present our statistical results, followed by a discussion of our findings, limitations, and scope for further research. We close the paper with our main conclusions. Our findings are of particular interest for policy makers, professionals in marketing management, and product developers to lever moving the sustainable transition in agricultural production.

2 Literature Review and Hypotheses Development

The present study aims to understand consumer attitudes and acceptance of pesticide-free animal food products.

To assess consumer attitudes and acceptance of pesticide-free food products, influencing factors have to be identified. From the literature, we derived four factors: *price sensitivity*, *health consciousness*, *chemophobia* and *perceived consumer effectiveness.*

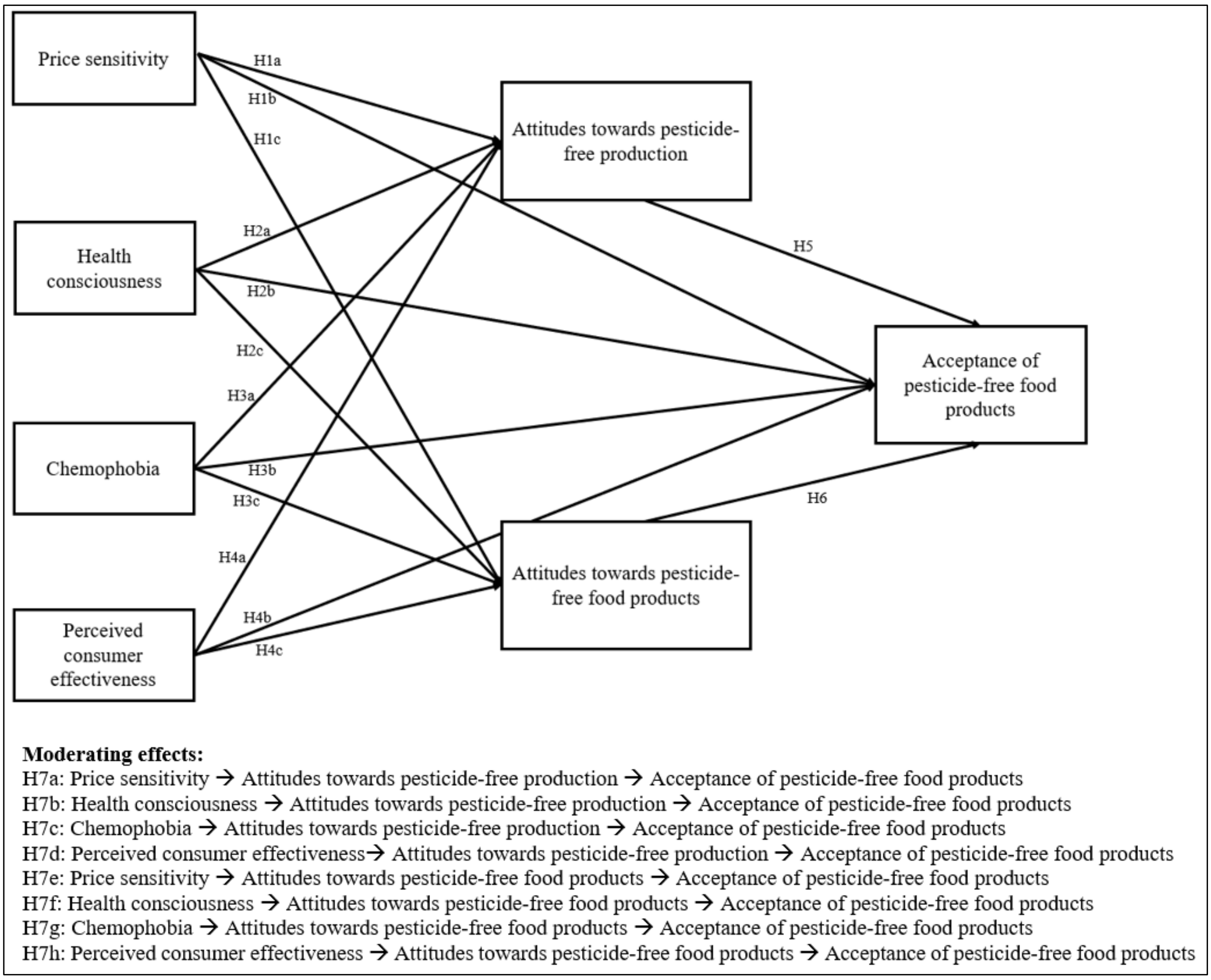

Figure 1. Research model

Source: own figure

Price Sensitivity

Price sensitivity reflects the extent to which consumer purchasing behaviour can be influenced by changes in the price levels of products (Goldsmith and Newell, 1997; Al-Mamun et al., 2014). According to Han et al. (2001) and Ghali-Zinoubi and Toukabri (2019), consumers with a high price sensitivity primarily consider price when making purchasing decisions. They tend not to buy organic foods, as they are usually more expensive (Ghali-Zinoubi and Toukabri, 2019), and they will respond strongly to price changes. In turn, consumers with little price sensitivity respond weakly to price changes; for these price-insensitive consumers, price tends not to play the primary role in a purchasing decision (Wang et al., 2020). Consumers with low price sensitivity incorporate non-price factors such as food safety and quality into their purchase decisions. Thus, price-insensitive consumers purchase more green products, e.g., organic foods, as they tend to ignore the price premium and adopt a more intentional attitude toward the products themselves (Wang et al., 2020). Accordingly, we established the following hypotheses:

H1a: Higher price sensitivity influences consumer attitudes towards pesticide-free production negatively.
H1b: Higher price sensitivity influences the acceptance of pesticide-free food products negatively.
H1c: Higher price sensitivity influences consumer attitudes towards pesticide-free food products negatively.

Health Consciousness

In recent years, consumers have become more concerned about food-related health issues and more involved in actions to preserve their health and wellbeing (Michaelidou and Hassan, 2010). As a result, many consumers have chosen organic food to avoid healthy issues related to pesticide residues (Koch et al., 2017; Wang et al., 2022; Parashar et al., 2023). In this context, health consciousness has proven to be a significant motive for the consumption of pesticide-free food products (Khan et al., 2018; Gundala and Singh, 2021; Parashar et al., 2023). Health consciousness refers to consumer concern about health issues as well as to consumer efforts to safeguard health (Chen, 2009; Pham et al., 2019). Recently, Farías (2020) and Gatti et al. (2022) have produced evidence that consumers are looking for pesticide-free properties in the foods they buy. This aligns with studies indicating that consumers value pesticide-free food products as healthier because of the absence of chemicals (Yiridoe et al., 2005; Farías, 2020). Consumers with a higher level of health consciousness thus are more likely to maintain a healthy lifestyle and more likely to purchase pesticide-free products (Khan et al., 2018; Gundala and Singh, 2021; Parashar et al., 2023), leading to the following hypotheses:

H2a: Higher health consciousness influences consumer attitudes towards pesticide-free food production positively.
H2b: Higher health consciousness influences the acceptance of pesticide-free food products positively.
H2c: Higher health consciousness influences consumer attitudes towards pesticide-free food products positively.

Chemophobia

The use of chemicals in food production has increasingly been met with public criticism and rejection (Jansen et al., 2020). A strong consumer demand for natural foods has resulted (Saleh et al. 2021). Recent studies have highlighted the absence of pesticides as one of the most important drivers for the purchase of organic foods (Gundala et al., 2021; Zheng et al., 2022). Gundala et al. (2021) state that consumers associate the absence of pesticides in foods with multiple benefits both to the environment and human health, and they consider pesticide-free products to be more reliable and more natural. Some people be prone to be excessively concerned about the risks associated with chemicals, believing that those cause harm in any concentration. The literature terms this *chemophobia* (Bearth et al., 2019; Saleh et al., 2019; Chalupa and Nesměrák, 2020). Chemophobics, who fear chemicals and avoid contact with them, would likely both favor pesticide-free food products and support banning chemicals in food production. Saleh et al. (2021) showed that chemophobia affects consumer acceptance of pesticide use and predicts the purchase of pesticide-free food products. Based on this, we propose the following hypotheses:

H3a: Higher chemophobia influences consumer attitudes towards pesticide-free food production positively.
H3b: Higher chemophobia influences the acceptance of pesticide-free food products positively.
H3c: Higher chemophobia influences consumer attitudes towards pesticide-free food products positively.

Perceived Consumer Effectiveness

Consumers have increasingly gained awareness of environmental challenges and the motivation to address these problems through environmentally friendly behaviour (Kim and Lee, 2023). The extent to which a consumer thinks that their activities will contribute to tackle an environmental issue can be interpreted as perceived consumer effectiveness (Tan, 2011). Tan (2011) indicated perceived consumer effectiveness to be an important determinant in understanding environmentally friendly behaviour. Perceived consumer effectiveness has also been marked as a significant factor in predicting purchase intention towards sustainable products. It has been detected to be linked directly to attitudes and consumer acceptance of green foods (Sharma and Dayal, 2017; Sharma and Foropon, 2019), and to correlate positively with green purchase intention and behaviour (D'Astous and Legendre, 2008; Gleim et al., 2013). Vermeir and Verbeke (2006) found the higher the perceived consumer effectiveness, the stronger the intention to buy sustainable products. These considerations lead to the following hypotheses:

H4a: Higher perceived consumer effectiveness influences consumer attitudes towards pesticide-free food production positively.
H4b: Higher perceived consumer effectiveness influences the acceptance of pesticide-free food products positively.
H4c: Higher perceived consumer effectiveness influences consumer attitudes towards pesticide-free food products positively.

Attitudes Towards Pesticide-Free Food Production

Studies show that consumers often describe the use of pesticides in food production as unnatural, unsafe, and problematic for human health and the environment. In turn, farming systems that avoid the use of pesticides evoke significantly more positive associations among consumers. Thus, consumers perceive pesticide-free food production as a system which offers food safety, naturalness, and environmental-friendliness (Koch et al., 2017; Simoglou and Roditakis, 2022; Ssemugabo et al., 2023). This leads us to the following hypothesis:

H5: Positive consumer attitudes towards pesticide-free production positively influence acceptance of pesticide-free food products.

Attitudes Towards Pesticide-Free Food Products

Studies have shown that consumer attitudes towards pesticide-free food products are linked to consumer purchase decisions. Farías (2020) highlighted that consumers who are convinced of the environmentally friendly properties of pesticide-free food products and who attribute a higher quality and value to these products indicate a higher purchase intention for pesticide-free food products. Additionally, results indicate that consumers interpret pesticide-free to mean safer, healthier, and less harmful. These positive consumer perceptions lead to a higher purchase intention for pesticide-free food products (Farías, 2020; Sapbamrer and Chittrakul, 2022), which leads to the following hypothesis:

H6: Positive consumer attitudes towards pesticide-free food products positively influence acceptance of pesticide-free food products.

Moderating Factors

This study also proposes attitudes towards pesticide-free production and attitudes towards pesticide-free food products serve as moderators of the relationships between acceptance of pesticide-free food products, and the four variables, *price sensitivity, health consciousness, chemophobia, and perceived consumer effectiveness.* Therefore, the following hypotheses are formulated to test if *attitudes towards pesticide-free production* and *attitudes towards pesticide-free food products* have moderating effects on *acceptance of pesticide-free food products*:

H7a: Positive attitudes towards pesticide-free production moderates the relationship between price sensitivity and acceptance of pesticide-free food products positively.
H7b: Positive attitudes towards pesticide-free production moderates the relationship between health consciousness and acceptance of pesticide-free food products positively.
H7c: Positive attitudes towards pesticide-free production moderates the relationship between chemophobia and acceptance of pesticide-free food products positively.

H7d: Positive attitudes towards pesticide-free production moderates the relationship between perceived consumer effectiveness and acceptance of pesticide-free food products positively.
H7e: Positive attitudes towards pesticide-free foods moderates the relationship between price sensitivity and acceptance of pesticide-free food products positively.
H7f: Positive attitudes towards pesticide-free foods moderates the relationship between health consciousness and acceptance of pesticide-free food products positively.
H7g: Positive attitudes towards pesticide-free food products moderates the relationship between chemophobia and acceptance of pesticide-free food products positively.
H7h: Positive attitudes towards pesticide-free food products moderates the relationship between perceived consumer effectiveness and acceptance of pesticide-free food products positively.

3 Material and Methods

As described below, we conducted an online-based questionnaire of German consumers to explore which factors influence consumer attitudes and acceptance of pesticide-free, but non-organic animal food products.

3.1 Data Collection and Sample

The data collection was administered via a professional online-panel provider in June 2022. According to the distribution of the German population (Federal Statistical Office, 2023), we set quotas for age, gender, household net income, education and German Federal State residency. Further, to ensure the quality of the data, we removed participants with implausible answers (n = 1) and those, who always selected the same response category (i.e., “speedliners”) (n = 10). The final sample consists of 1,010 Germans respondents. The sample consisted of participants between 18 and 82, of whom 49.7% were male. The average age of the sample was 49. The sociodemographic characteristics can be taken as a maximum representative sample of the German population in terms of age, gender, and region. Thus, this sample allows conclusions to be drawn for the German population. In terms of education and income, participants in our sample had a higher level of secondary and A-level education and a lower net household income compared to the German average (Federal Statistical Office, 2023). According to Kock and Hadaya (2018), we used the suggested inverse square root method to calculate the minimum sample size in PLS path modelling. We assumed a minimum path coefficient level of 0.1, a level of significance of 0.05 and a statistical power of 0.80. This equals a minimum sample size of 618. Having explorative research, we decided to oversample. However, we received path coefficients below 0.1. Thus, the robustness for those paths is limited.

The survey (compare supplementary material)[1] was approved by a data protection officer and was ethically authorized by the ethics committee of the University of Hohenheim. The questionnaire was structured into several sections to separate the sociodemographic variables of age, gender, region, monthly net income, education level, number of household members, and number of children (Federal Statistic Office, 2023). Consumer attitudes towards pesticide-free food products and pesticide-free food production (modified from Voss, 2008; Bruner, 2017), and acceptance of pesticide-free food products (modified from Hocquette et al., 2016; Wilks and Phillips, 2017) were assessed. Further, statements were collected to characterize price sensitivity (Gil and Soler, 2006), environmental awareness (Kim and Choi, 2005; Wesley et al., 2012), health consciousness (Michaelidou and Hassan, 2008), relevance of product information (Grunert et al., 1993) and chemophobia (Saleh et al., 2021).

1 https://doi.org/10.5281/zenodo.11382984

3.2 Measures

For our statistical analysis, we derived seven measurement scales from the literature as described below.[2]

Price sensitivity: Adopted from Gil and Soler (2006), the scale to measure price sensitivity consisted of three items. The five-point Likert scale ranged from 1 (strongly disagree) to 5 (strongly agree).

Health consciousness: The study measured health attitudes using five items adopted from Michaelidou and Hassan (2008) on a five-point Likert scale (strongly disagree (1) to strongly agree (5)).

Chemophobia: Adopted from Saleh et al. (2021), a six-item scale was used to measure chemophobia. Respondents completed the measure using a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5).

Perceived consumer effectiveness: The study measured self-efficacy using six items adopted from Kim and Choi (2005) and Wesley et al. (2012) on a five-point Likert scale (strongly disagree (1) to strongly agree (5)).

Attitudes towards pesticide-free production: Nine items to measure attitudes towards pesticide-free production were modified from Voss (2008) and presented using a bipolar response scale with five scale points.

Attitudes towards pesticide-free food products: Attitudes towards pesticide-free food products were measured using six items modified from Bruner (2017) and presented on five-point Likert scales ranging from strongly disagree (1) to strongly agree (5).

Acceptance of pesticide-free food products: Acceptance of pesticide-free food products was measured using 15 items modified from Hocquette et al. (2016) and Wilks and Phillips (2017). Respondents completed the measure using five-point Likert scales (strongly disagree (1) to strongly agree (5)).

The description of the full scales can be found in Appendix A.

4 Statistical Results

Partial least squares structural equation modelling (PLS-SEM) is appropriate for explorative research and hypothesis testing, and it is especially suitable for non-normal distributed data (Hair et al., 2022). Thus, for the statistical analysis, we used the PLS-SEM software SmartPLS4 (Ringle et al., 2022). The analysis consisted of two steps (Hair et al., 2011): first, the assessment of the reliability and validity of the measurement model (outer model, described in Section 4.1) and second, the assessment of the structural model's fit (inner model, described in Section 4.2). The model is reflective.

4.1 Measurement Model

First, we carried out explorative factor analyses to identify all relevant items for the respective latent variable which are shown in Figure 1. All items with an outer loading of less than 0.4 were removed from the model to avoid double loadings, except cheese with an outer loading of 0.398. Cheese was kept, first because 0.398 is close to 0.4, but primarily for consistency: The respective items for milk and butter were above the threshold and thus included. All other

[2] The addition "modified" means that we have modified this scale so that it refers to "pesticide-free food products".

variables were above the threshold of 0.7 (one item each for *acceptance of pesticide-free food products*, *health consciousness* and *chemophobia*) (Hair et al., 2022). Reliability tests showed that removing these items did not improve internal consistency reliability. Thus, we included these items in the analysis.

We applied Cronbach's Alpha (CA) and composite reliability (CR) to test for internal consistency reliability. All constructs are above the threshold for both reliability factors (>=0.7) (Hair et al. 2022). Further, the Average Variance Extracted (AVE) also meets the threshold of 0.5 for all constructs as recommended by Hair et al. (2022). Table 1 shows the results of internal reliability and validity tests for all constructs.

Table 1. Internal reliability and validity

Construct	Number of items	Cronbach's Alpha (CA) (>=0.7)	Composite Reliability (CR) (>=0.7)	Average Variance Extracted (AVE) (>=0.5)
Acceptance of pesticide-free food products (ACC)	15	0.952	0.958	0.631
Attitudes towards pesticide-free production (APFP)	9	0.937	0.948	0.669
Attitudes towards pesticide-free food products (APFF)	6	0.933	0.935	0.751
Perceived consumer effectiveness (PCE)	6	0.917	0.948	0.707
Chemophobia (C)	6	0.863	0.896	0.591
Health consciousness (HC)	5	0.855	0.898	0.640
Price sensitivity (PS)	3	0.847	0.924	0.859

Source: own calculations

Discriminant validity was assessed by the Fornell-Larcker criterion, the Heterotrait-Monotrait ratio of correlations (HTMT) criterion, and cross-loadings. Table 2 shows the results. All assigned variables should explain the variance better than any other latent variables (Fornell and Larcker, 1981). Table 2 reveals that this criterion is met. Henseler et al. (2015) further recommend for the PLS-SEM-based discriminant validity assessment the HTMT criterion. As our HTMT value is below the 0.9 threshold, discriminant validity has been established. Further, we assessed multicollinearity by applying VIF values. All values are below the threshold of 5 (Hair et al., 2022). So, there is no hint for collinearity.

Further, each indicator's loading on its assigned latent variable should be higher than on any other latent variables. The results show there are no cross loadings (data available on request). Thus, the results for the three criteria supports discriminant validity.

Table 2. Discriminant validity (Fornell-Larcker criterion & HTMT matrix)

Construct	*ACC*	*APFP*	*APFF*	*PCE*	*C*	*HC*	*PS*
ACC		0.538	0.714	0.597	0.399	0.481	0.084
APFP			0.580	0.426	0.160	0.220	0.045
APFF				0.656	0.376	0.434	0.043
PCE					0.468	0.537	0.063
C						0.556	0.034
HC							0.092
PS							

Source: own calculations

4.2 Structural Model

We found an adjusted R-squared of 0.534 for *ACC.* This means that 53.4% of the latent variables variance is explained moderately by the assigned items (Hair et al., 2011). For *APFF* we found adjusted R^2 to be 0.388 and for *APFP* we found 0.162. For f-square, we found a moderate effect for *APFF* on *ACC* (0.175) and a moderate effect for *PCE* on *APFP* (0.143) and a large effect on *APFF* (0.332) (Cohen, 1988). All other effect sizes were smaller. For predictive power, we applied CVPAT following Hair et al. (2022). The IA benchmark provided by PLSpredict (Shmueli et al., 2016, 2019) showed significantly negative average losses and thus indicates predictive power.

We assessed the inner model (structural model) by applying a bootstrapping routine with 5,000 subsamples, a two-tailed testing type and a significance level of 0.05. Table 3 provides the results of the direct effects and Table 4 displays the results for the moderating effects.

Table 3. Structural model (direct effects)

Hypothesis	Direct effect	Beta	Confidence intervals bias corrected	Standard deviation	t-value	P value	Decision
H1a	*PS -> APFP*	0.052	[-0.012, 0.114]	0.033	1.599	0.110	Unsupported
H1b	***PS -> ACC***	**-0.045**	[-0.085, 0.001]	**0.022**	**2.046**	**0.041**	**Supported**
H1c	*PS -> APFF*	-0.005	[-0.056, 0.044]	0.026	0.194	0.846	Unsupported
H2a	*HC -> APFP*	0.023	[-0.044, 0.089]	0.034	0.669	0.503	Unsupported
H2b	***HC -> ACC***	**0.140**	[0.084, 0.193]	**0.028**	**4.957**	**0.000**	**Supported**
H2c	***HC -> APFF***	**0.097**	[0.035, 0.156]	**0.032**	**3.063**	**0.002**	**Supported**
H3a	*C -> APFP*	-0.032	[-0.099, 0.034]	0.034	0.953	0.340	Unsupported
H3b	***C -> ACC***	**0.083**	[0.031, 0.140]	**0.028**	**2.937**	**0.003**	**Supported**
H3c	***C -> APFF***	**0.077**	[0.019, 0.135]	**0.030**	**2.595**	**0.009**	**Supported**
H4a	***PCE -> APFP***	**0.408**	[0.338, 0.474]	**0.034**	**11.859**	**0.000**	**Supported**
H4b	***PCE -> ACC***	**0.145**	[0.075, 0.218]	**0.036**	**3.995**	**0.000**	**Supported**
H4c	***PCE -> APFF***	**0.531**	[0.464, 0.594]	**0.034**	**15.809**	**0.000**	**Supported**
H5	***APFP -> ACC***	**0.195**	[0.132, 0.274]	**0.036**	**5.474**	**0.000**	**Supported**
H6	***APFF -> ACC***	**0.396**	[0.316, 0.473]	**0.040**	**9.972**	**0.000**	**Supported**

Source: own calculations

Ten out of our fourteen hypotheses are supported by our statistical analyses. These are marked 'Supported' in Table 3. Further, in Figure 2, we provide the significant results in a graphical presentation.

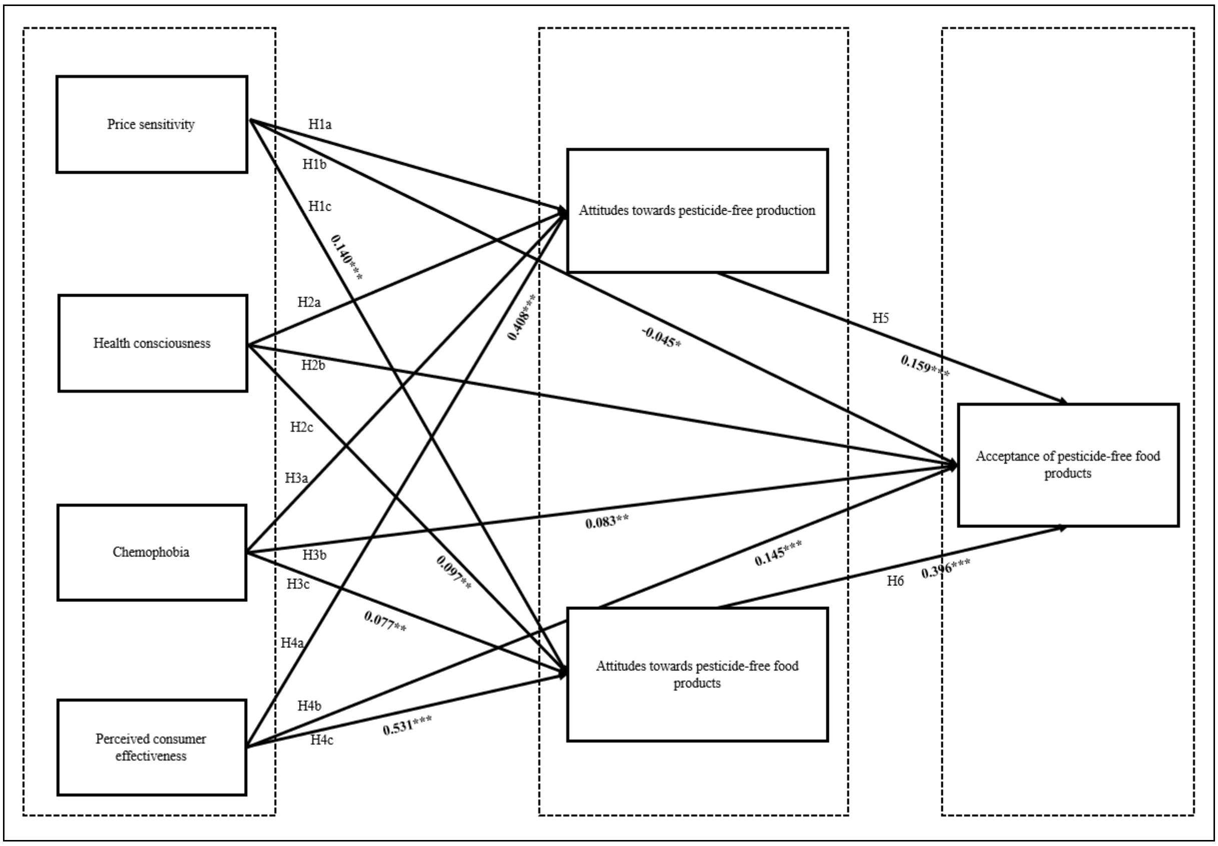

Figure 2. Statistical results

Source: own calculations

Price Sensitivity seems to have a statistically significant influence on *ACC* (beta = -0.045) but influences neither *Attitude*. Thus, if *PS* increases by one unit of standard deviation, *ACC* will decrease, ceteris paribus, by 0.045 units of standard deviation. This means that the more price sensitive respondents are, the weaker their *ACC* for pesticide-free milk, cheese, and butter.

A positive attitude towards *Health Consciousness* positively influences the *ACC* (beta = 0.140) as well as the *APFF* (beta = 0.097) although the influence of *HC* is stronger on *ACC* than on *APFF*. Furthermore, *Chemophobia* shows the same statistically significant positive influence on *ACC* (beta = 0.083) and *APFF* (beta = 0.077) although the influence is weaker than *HC's*. This means that the more chemophobic a person is, the greater effect the phobia has on *ACC* and *APFF*.

Of all the latent variables, *PCE* shows the highest beta coefficients for its influence on *APFP* (0.408), *APFF* (beta = 0.531) and *ACC* (beta = 0.145).

Further, *APFP* and *APFF* both positively influence the *ACC* for pesticide-free produced milk, butter, and cheese (beta = 0.195 and beta = 0.396, respectively).

Table 4. Structural model (specific indirect effects)

Hypo-thesis	Moderating effects	Beta	Standard deviation	t-value	P value	Decision
H7a	*PS -> APFP -> ACC*	0.010	0.007	1.498	0.134	Unsupported
H7b	*HC -> APFP -> ACC*	0.004	0.007	0.658	0.511	Unsupported
H7c	*C -> APFP -> ACC*	-0.006	0.007	0.927	0.354	Unsupported
H7d	***PCE -> APFP -> ACC***	**0.080**	**0.016**	**4.964**	**0.000**	**Supported**
H7e	*PS -> APFF -> ACC*	-0.002	0.010	0.193	0.847	Unsupported
H7f	***HC -> APFF -> ACC***	**0.039**	**0.013**	**2.885**	**0.004**	**Supported**
H7g	***C -> APFF -> ACC***	**0.031**	**0.013**	**2.438**	**0.015**	**Supported**
H7h	***PCE -> APFF -> ACC***	**0.210**	**0.025**	**8.372**	**0.000**	**Supported**

Source: own calculations

We found statistically significant support for four of the eight moderation paths. Thus, hypotheses H7d ($p < 0.001$), H7f ($p < 0.01$) as well as H7g ($p < 0.05$) and H7h ($p < 0.001$) are supported. Of the latent variables, *PCE* shows the strongest moderation effect, with its influence on *ACC* being statistically significant strengthened by both *APFP* and *APFF*. The stronger the *PCE*, the stronger is the moderation effect of *APFP* and also *APFF* on *ACC*. We further found *APFF* to be a moderator for the effect of *C* and *HC* towards *ACC*. Thus, the influence on *ACC* of *HC* and *C* is stronger the more *APFF* is pronounced. However, we highlight that all moderation effects are very small.

5 Discussion

To assess consumer acceptance of an innovative agricultural system that offers pesticide-free production while retaining non-organic fertilizer use, we conducted an online-based survey with 1,010 German consumers. We tested fourteen hypotheses to assess the direct effects of the variables on *ACC*, as well as eight hypotheses to assess the moderating effects.

In terms of the direct effects, we found support for ten of the fourteen hypotheses. H1b, hypothesizing an influence of *PS* on *ACC,* was supported, in agreement with prior findings (Wang et al., 2020). Results in our study highlighted that *PS* has a statistically significant negative effect on *ACC*, meaning the more price-sensitive consumers are, the weaker the *ACC*. As pesticide-free products are expected to be more expensive than conventional ones, these products will be more attractive to the less price sensitive consumer for whom non-price factors such as the absence of pesticides and food safety are primary considerations in purchase decisions. Similarly, Ghali-Zinoubi and Toukabri (2019) reported that the stronger the *PS*, the more likely price-sensitive consumers would not buy pesticide-free food products and would reject the entire concept along with-it products. Due to this fact, it is surprising that price sensitivity showed no effect on either attitude (H1a and H1c). We suspect that the participants were not yet fully aware of the pesticide-free farming concept. If these products were to come onto the market, a study could investigate this influence again once awareness and knowledge of this farming system has been raised.

Similarly, health consciousness did not influence attitudes toward food production (H2a). This could also be due to the participants' lack of judgment about the new farming system. *HC* did positively influence attitudes toward food products, however (H2c). And *HC* influenced *ACC*, as hypothesized (H2b), and in agreement with prior findings (Khan et al., 2018; Gundala and Singh, 2021; Parashar et al., 2023). Indeed, our results reveal a strong positive direct effect of *HC* on *ACC*. These findings imply that health consciousness motivates consumers to make purchase decisions to avoid pesticide residues. These consumers would likely be open to buying pesticide-free products. Professionals in the food industry as well as marketing managers creating labelling systems and marketing strategies for pesticide-free food products should consider the effect of health claims on the product's primary display panel. The influence of *HC* on *APFF* is consistent with findings from Parashar et al. (2023) showing that health-conscious consumers tend to pay more attention to products with pesticide-free characteristics. Messaging that links pesticide-free to health-promoting will likely be effective.

Further, although its influence is weaker than *HC's*, chemophobia *C* has a statistically significant, but small, positive direct influence on both *ACC* (H3b) and *APFF* (H3c). This means that the more chemophobic a person is, the stronger the *ACC* and the *APFF*. These influences are probably the outcome of the fact that consumers with a high fear of chemicals consider pesticide-free food products safer due to the absence of pesticide residues, and this acts as a stimulus for the internal factors represented by *APFF* and the response represented by *ACC*. Our findings are in line with other studies that have linked chemophobia to the acceptance of pesticide-free food products (Saleh et al., 2021). Farías (2020) suggests that policymakers could require producers and retailers to openly communicate the presence or absence of pesticides and specific environmental and consumer health impacts. Future research should investigate the design and perception of pesticide-free labelling on the front of products. Further, as mentioned by Saleh et al. (2021), chemophobic consumers support a ban on the use of chemicals in food production and see many benefits associated with pesticide-free food production. Thus, it is surprising that *C* was found to have no significant direct influence on *APFP* in our study (H3a).

The fourth stimulus variable examined in this study is *perceived consumer effectiveness,* the extent to which consumers believe that their individual actions can make a difference in environmental issues. *PCE* was found to have a statistically significant positive direct influence on *APFP* (H4a) as well as *ACC* (H4b) and *APFF* (H4c). This may be attributed to the fact that consumers who feel responsible for their impact on the environment will take positive steps to support cleaner methods of production, which will then influence their environmental behaviour. In the context of this study, the more individuals believe their actions will contribute to solving an environmental issue, the stronger is their buying intention for pesticide-free food products. Consumers with a strong *PCE* tend to focus more on environmental protection than those who perceive their actions as inconsequential, which results in a preference for and a high rate of adoption of green foods. Our findings are in line with previous findings by Vermeir and Verbeke (2006 and 2008), who reported that *PCE* is an important determinant to explain *ACC* and attitudes towards green foods.

In addition, results show that *APFP* and *APFF* have a statistically significant positive direct influence on *ACC* for pesticide-free food products (H5 and H6). Previous studies (Farías 2020; Wang et al., 2022) have indicated that consumers make a number of positive associations to pesticide-free food products, two prominent of which are causing less harm to human health and the environment. This leads to a greater acceptance of pesticide-free food products. Interestingly, we find the effect of *APFF* on *ACC* is stronger than that of *APFP*. This might be due to the fact that most consumers are not familiar with modern intensive livestock production systems and thus have a clearer idea about the products themselves than about the production processes (Clark et al., 2019). However, for a long-term and successful establishment of pesticide-free farm products in the market, it is essential that consumers understand the basic features of the new farming system and can differentiate among conventional, organic, and pesticide-free methods of food production. Thus, when implementing marketing and labelling strategies, strategic marketing planning should also strongly focus on education campaigns for pesticide-free farming.

The study also examined moderation effects, for which four of the eight hypotheses tested can be supported. *APFF* positively moderates three of the four stimulus variables – *HC, C* and *PCE* – towards *ACC* (H7f, H7g, and H7h). However, the moderation effect of *APFF* is the strongest on *PCE* and *ACC*. Further, H7d, proposing a moderation effect of *APFP* on the effect of *PCE* towards *ACC*, was supported, as the results indicate that the influence on *ACC* of *PCE* is stronger the more pronounced *APFP*. In comparison, H7a, H7b, and H7c, proposing the moderating effect of *APFP* on *PS*, *HC*, *C* and *ACC*, were not supported. This might be due to a lack of familiarity with modern intensive livestock production systems. Further, *APFF* does not have a moderating effect on *PS* and *ACC* (H7e). This could be due to the fact that for price-sensitive consumers, it is irrelevant how convinced or unconvinced they are about the product, and thus there is no impact on their acceptance of pesticide-free food products.

In sum, the results of this study have shown that *PS*, *HC*, *C*, *PCE*, *APFP*, and *APFF* are all significant predictors of *ACC* in our study. However, the influence of *APFP* and *APFF* on *ACC* are the strongest. Moreover, *PCE* was found to have a strong influence on *APFP*. Further, *HC* and *PCE* were found to have a statistically significant influence on *APFF*. Within the scope of all direct effects, the effect of *PCE* on *APFF* is the strongest. The found statistically significant effects of *HC*, *C* and *PS* on *ACC* were rather small effects (beta coefficients < 0.1).

The study offers important input for policy makers, producers, and marketers of pesticide-free food products. These findings underscore the necessity of a positive basic attitude towards the new farming system for its successful establishment in the food market. In this line, targeted information about the new farming system can have a significant influence on consumers acceptance and offers the possibility that attitudes and consumers acceptance could be changed. Thus, running campaigns should create awareness for recent intense agricultural production systems and more sustainability-oriented production systems. This implies that marketing campaign messages highlight the benefits of pesticide-free food production for human health and for the environment. Likewise, awareness should be raised among the population that each individual can make a significant contribution to solving climate-related challenges by making careful product choices. Highlighting the benefits of pesticide-free food products over conventional as well as organic foods offers the opportunity to educate consumers and trigger acceptance of pesticide-free food products.

Certain limitations of our study should be kept in mind. First, we have used data generated from an online-based questionnaire, which may have been affected by biases, including a social desirability bias. Second, we focused on German consumer attitudes, which may not be generalizable to other countries and contexts. Third, the study focuses on three animal food products (milk, butter, and cheese), and so results cannot be generalized to the totality of products, whether animal, plant, or processed and non-processed foods. Future research can address these questions by iterating our study in various countries and by examining consumer acceptance of a broader range of products. This would help identify potential acceptance differences between different consumer cultures or product groups.

Moreover, further qualitative studies could clarify consumer conceptions, or misconceptions, of the new pesticide-free farming system. Missing or incorrect information could then be remedied through appropriate communication strategies.

Additionally, for marketing strategies for pesticide-free food products to be effective in promoting this new farming concept, they require deeper insights into the effect of product packaging on consumer buying behaviour. These could inform design of packaging for pesticide-free food products and so position these products in the market to evoke positive associations among those consumers who would be likely to avoid pesticide residues in their food.

6 Conclusion

The current use of pesticides in modern agriculture calls for a system change. The intensified application of pesticides puts a heavy burden on the environment, which causes negative effects on water, soil, and air contamination as well as biodiversity (Rockström et al., 2009; Sánchez-Bayo and Wyckhuys, 2019; Pelosi et al., 2021). For an innovative pesticide-free farming system to contribute to the transition to cleaner agricultural production, consumer acceptance of food produced by this system is essential. We assessed consumer attitudes and acceptance using partial least squares structural equation modelling (PLS-SEM) to address the following research question:

Which factors influence German consumer attitudes and acceptance of pesticide-free, but non-organic animal food products?

Analysing influencing factors shows that price sensitivity is an inhibitor of the acceptance of these products. Thus, when planning to introduce pesticide-free food into retail channels, marketing management should concentrate on emphasizing the benefits of the production system for human health and the environment, e.g., by providing information at the point of sale. Positive drivers for the acceptance of pesticide-free foods are health consciousness, chemophobia and perceived consumer effectiveness. Those core drivers should be addressed in communication strategies and incorporated into future consumer research as well as marketing strategies.

Further, it needs to be made clear to consumers by marketing communication tools such as labelling on the products' front display that this is a market segment between conventional and organic farming, such as the planet score does. This multi-level label rates, e.g., use of pesticides and biodiversity. For animal welfare, a product segment between conventional and organic has already been established, which has increased animal welfare. This could also be the future of products for pesticide-free food: being a solid offer on supermarket shelves and relieving the burden that the intensified use of pesticides puts on the environment. Beyond that, the advantages of the production system, highlighted by several researchers, and the products themselves need to be clear to the consumer. This is also a task for policy: consumers' disconnection from the realities of modern farming leads to less awareness of modern agriculture and, consequently, to less informed decision-making by consumers if they are not aware of the use of pesticides in agriculture.

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Contact author

Marie-Catherine Wendt
Department of Consumer Behaviour in the Bioeconomy
University of Hohenheim
Wollgrasweg 49, 70599 Stuttgart, Germany
e-mail: mariecatherine.wendt@uni-hohenheim.de

Appendix

Appendix A. Scales

Price sensitivity

1. I try to buy food that is on sale.
2. I look out for good deals.
3. I compare the prices of different brands of food.

Health consciousness

1. I take care of my health.
2. I maintain a healthy lifestyle.
3. I value a healthy lifestyle.
4. I think a lot about my health.
5. I notice changes in my health.

Chemophobia

1. I am afraid of chemical substances that I can't even pronounce.
2. Chemical substances scare me.
3. I would like to live in a world where there are no chemicals.
4. The chemical industry is responsible for more and more people getting cancer.
5. In a world without chemicals, there would be no environmental disasters.
6. I do everything I can to avoid contact with chemical substances in my everyday life.

Perceived consumer effectiveness

1. Every consumer can have a positive impact on society by buying environmentally friendly products.
2. Each individual can influence the quality of the environment by choosing products carefully.
3. I can protect the environment by buying products that are environmentally friendly.
4. I feel able to contribute to solving environmental problems by buying environmentally friendly products.
5. I feel able to contribute to solving environmental problems.
6. What I buy as a consumer has an impact on the environmental problems of the country of origin.

Attitudes towards pesticide-free production

1. Healthy – unhealthy
2. Rural – industrial
3. Modern – old-fashioned
4. Environmentally friendly – environmentally unfriendly
5. Close to nature – far from nature
6. Unproblematic – problematic
7. Harmless – questionable
8. Safe – unsafe
9. Animal-friendly – not animal-friendly

Attitudes towards pesticide-free food products

1. Milk, cheese, and butter produced without the use of pesticides are good for the environment.
2. Milk, cheese, and butter produced without the use of pesticides can effectively reduce environmental impact.
3. Environmental relief can contribute to an intact ecosystem.
4. Environmental relief would have many benefits, such as the reduction of insect mortality and the relief of water bodies.
5. Milk, cheese, and butter produced without the use of pesticides would make the product more valuable.
6. Milk, cheese, and butter produced without the use of pesticides would I find good.

Acceptance of pesticide-free food products

1. I would buy milk using feed produced without pesticides.
2. I would taste milk using feed produced without pesticides.
3. I would regularly drink milk using feed produced without pesticides.
4. I would recommend milk produced without pesticides to my friends and family.
5. I would prefer milk using feed produced without pesticides if the product is identified by an independent label.
6. I would buy cheese using feed produced without pesticides.
7. I would taste cheese using feed produced without pesticides.
8. I would regularly eat cheese using feed produced without pesticides.
9. I would recommend cheese produced without pesticides to my friends and family.
10. I would prefer cheese using feed produced without pesticides if the product is identified by an independent label.
11. I would buy butter using feed produced without pesticides.
12. I would taste butter using feed produced without pesticides.
13. I would regularly eat butter using feed produced without pesticides.
14. I would recommend butter produced without pesticides to my friends and family.
15. I would prefer butter using feed produced without pesticides if the product is identified by an independent label.

Appendix B. Descriptive Results

Table B.1. Descriptive results for the question "How would you rate your level of knowledge on this topic?" (N = 1,010)

Very poor	Rather poor	Neither	Rather goof	Very good	$\bar{x}$
9,9 (100)	28,3 (286)	28,6 (289)	27,7 (280)	5,4 (55)	-0,10

Source: own calculations

Table B.2. Descriptive results for the question "How often have you heard, seen or read about pesticide residues in food in the last 12 months?" (N = 1,010)

Never	Rarely	Occasionally	Often	Very often	$\bar{x}$
19,3 (195)	28,0 (283)	34,6 (349)	14,5 (146)	3,7 (37)	-0,45

Source: own calculations

Table B.3. Descriptive results for the question "How interested are you personally in the possible risks of pesticide residues in food?" (N = 1,010)

Not at all	Less strongly	Undecided	Strongly	Very strongly	$\bar{x}$
5,9 (60)	10,0 (101)	35,1 (355)	34,9 (352)	14,1 (142)	0,41

Source: own calculations

Table B.4. Descriptive results for the question "What is your opinion on the following statements?" (N = 1,010)

Statement	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree	I cannot not assess	$\bar{x}$
Pesticides increase agricultural productivity.	2,7 (27)	5,4 (55)	19,3 (195)	32,9 (332)	32,6 (329)	7,1 (72)	0,94
Pesticides are harmless to humans when used properly.	13,6 (137)	18,7 (189)	30,3 (306)	18,1 (183)	10,5 (106)	8,8 (89)	-0,07
Pesticides are harmless to the environment when used properly.	16,5 (167)	24,7 (249)	25,4 (257)	15,4 (156)	9,4 (95)	8,5 (86)	-0,26
Pesticides are harmless to insects when used properly.	20,8 (210)	24,6 (248)	23,7 (239)	13,7 (138)	8,2 (83)	9,1 (92)	-0,40
Pesticides are necessary for the production of food.	15,6 (158)	19,5 (197)	32,1 (324)	15,1 (153)	8,8 (89)	8,8 (89)	-0,20

Source: own calculations

Table B.5. Descriptive results for the question "What is your opinion on the following statements?" (N = 1010). Milk, cheese and butter produced without the use of pesticides...

Statement	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree	$\bar{x}$
… are good for the environment.	1,1 (11)	2,7 (27)	12,3 (124)	33,6 (339)	50,4 (509)	1,3
... can help preserve the ecosystem.	1,2 (12)	2,6 (26)	15,9 (161)	35,9 (363)	44,4 (448)	1,2
... can effectively reduce environmental impact.	1,5 (15)	2,3 (23)	17,4 (176)	33,9 (342)	45,0 (454)	1,19
I would find milk, cheese, and butter produced without the use of pesticides good.	1,0 (10)	2,5 (25)	13,7 (138)	30,9 (312)	52,0 (525)	1,3
... would have many benefits.	1,0 (10)	2,3 (23)	15,1 (153)	35,2 (356)	46,3 (468)	1,24
... would make the product more valuable.	1,8 (18)	3,8 (38)	15,2 (154)	32,1 (324)	47,1 (476)	1,19

Source: own calculations

Table B.6. Descriptive results for the question "What is your opinion on the following statements?" (N = 1010). I find the production of milk, butter and cheese without the use of pesticides...

	Very	Somewhat	Undecided	Somewhat	Very		$\bar{x}$
unhealthy	4,0 (40)	5,1 (52)	11,9 (120)	24,4 (246)	54,7 (552)	healthy	1,21
industrial	4,9 (49)	7,0 (71)	19,6 (198)	26,3 (266)	42,2 (426)	rural	0,94
old-fashioned	3,1 (31)	7,0 (71)	19,9 (201)	24,3 (245)	45,7 (462)	modern	1,03
environmentally unfriendly	4,2 (42)	4,9 (49)	13,1 (132)	23,7 (239)	54,3 (548)	environmentally friendly	1,19
far from nature	5,0 (51)	5,3 (54)	10,6 (107)	24,3 (245)	54,8 (553)	close to nature	1,18
problematic	4,3 (43)	10,1 (102)	29,6 (299)	24,6 (248)	31,5 (318)	unproblematic	0,69
questionable	4,0 (40)	7,0 (71)	20,3 (205)	26,4 (267)	42,3 (427)	harmless	0,96
unsafe	3,8 (38)	5,8 (59)	19,8 (200)	27,5 (278)	43,1 (435)	safe	1,0
not animal friendly	4,2 (42)	5,0 (51)	15,6 (158)	22,4 (226)	52,8 (533)	animal friendly	1,15

Source: own calculations

Table B.7. Descriptive results for the question "What is your opinion on the following statements?" (N = 1,010)

Statement	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree	$\bar{x}$
I would buy milk produced without pesticides.	1,9 (19)	3,4 (34)	19,1 (193)	30,2 (305)	45,4 (459)	1,14
I would taste milk produced without pesticides.	1,6 (16)	2,6 (26)	10,7 (108)	27,2 (775)	57,9 (585)	1,37
I would regularly eat milk produced without pesticides.	3,5 (35)	4,6 (46)	25,0(252)	30,6 (309)	36,4 (368)	0,92
I would recommend milk produced without pesticides to my friends and family.	2,2 (22)	4,3 (43)	20,8 (210)	29,9 (302)	42,9 (433)	1,07
I would prefer milk produced without pesticides if the product were identified by an independent label.	3,1 (31)	4,5 (45)	20,1 (203)	31,4 (317)	41,0 (414)	1,03

Source: own calculations

Table B.8. Descriptive results for the question "What is your opinion on the following statements?" (N = 1,010)

Statement	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree	$\bar{x}$
I would buy cheese produced without pesticides.	1,6 (16)	4,1 (41)	18,8 (190)	30,9 (312)	44,6 (451)	1,13
I would taste cheese produced without pesticides.	10,3 (104)	20,1 (203)	11,9 (120)	16,3 (165)	41,4 (418)	0,58
I would regularly eat cheese produced without pesticides.	2,1 (21)	4,4 (44)	23,1 (233)	31,0 (313)	39,5 (399)	1,01
I would recommend cheese produced without pesticides to my friends and family.	2,1 (21)	3,2 (32)	20,5 (207)	32,0 (323)	42,3 (427)	1,09
I would prefer cheese produced without pesticides if the product were identified by an independent label.	2,6 (26)	4,2 (42)	20,5 (207)	31,4 (317)	41,4 (418)	1,05

Source: own calculations

Table B.9. Descriptive results for the question "What is your opinion on the following statements?" (N = 1,010)

Statement	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree	$\bar{x}$
I would buy butter produced without pesticides.	1,5 (15)	3,5 (35)	19,5 (197)	31,6 (319)	44,0 (444)	1,13
I would taste butter produced without pesticides.	1,5 (15)	3,2 (32)	10,6 (107)	29,4 (297)	55,3 (559)	1,34
I would regularly eat butter produced without pesticides.	3,0 (30)	4,2 (42)	23,8 (240)	29,7 (300)	39,4 (398)	0,98
I would recommend butter produced without pesticides to my friends and family.	2,5 (25)	3,7 (37)	20,8 (210)	30,4 (307)	42,7 (431)	1,07
I would prefer cheese produced without pesticides if the product were identified by an independent label.	13,3 (134)	16,7 (169)	22,2 (242)	19,3 (195)	28,5 (288)	0,33

Source: own calculations