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Article

Willingness to purchase selenium- and iodine-biofortified apples – a discrete choice analysis with German consumers

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Abstract:

Selenium and iodine are essential micronutrients for humans. They are often deficient in food supply due to low phytoavailable concentrations in soil. Agronomic biofortification of food crops is one approach to overcome micronutrient malnutrition. This study focused on German consumers' willingness to purchase selenium- and/or iodine-biofortified apples. For this purpose, an online survey was carried out. In this context, consumers were asked to choose their most preferred apple product from a set card of product alternatives (Discrete Choice Experiment). The multinomial logit model results demonstrated that German consumers' have a preference in particular for iodine-biofortified apples. Furthermore, apple choice was mainly influenced by price, health claims, and plastic-free packaging material. Viewed individually, selenium did not exert an effect on product choice whereas positive interactions between both micronutrients exist.

Keywords: biofortification; discrete choice; fruits; health claims; micronutrients

1. Introduction

Selenium and iodine are essential micronutrients for human health. They are responsible for the proper functioning of the thyroid and the immune system as well as for the prevention of cancer [1–3]. In large parts of Europe and other regions of the world, the selenium and iodine content in soils of agricultural land is relatively low [4–7]. As a consequence, the population exhibits deficiencies of the micronutrient due to the likewise low selenium content in agricultural products [8]. Globally, approximately 15% of the population were insufficiently supplied with selenium and 30% with iodine [9]. Different measures were taken in order to prevent the population from the resulting diseases. For example, table salt was often enriched with iodine and made available in supermarkets [10]. Contrarily, a similar product containing selenium was not available so far. Different agricultural practices were applied that increased the supply of micronutrients in food. Examples include supplementation of feed for livestock with micronutrients selenium and iodine, resulting in increased levels of these micronutrients in meat and milk respectively [2,11].

Another approach is the agronomic biofortification of crops where micronutrients were enriched in plants via fertilization. This technique proved to be effective for increasing the selenium and iodine content in plant-based food [12,13]. Field experiments were successfully carried out for apples and other fruits [14–17]. D'Amato et al. compiled numerous attempts of biofortification of food crops with selenium. The authors highlight that biofortified selenium is well bioavailable for the human body due to its incorporation into organic compounds such as amino acids [18]. In addition, the biofortification of food crops may provide other benefits. For example, in experiments with pears and peaches, foliar selenium sprays resulted in increased soluble solids content and firmness of the fruits,

respectively [19]. Furthermore, both selenium and iodine fertilization can promote the formation of valuable plant substances such as Vitamin C and phenolic compounds [20,21].

Among consumers, awareness of food consumption and healthy diets raised significantly. Their intention is to increase the personal well-being and prevent diseases which could result from unfavorable food choices [22]. Concerning trends in food purchase, a shift from highly processed foods towards healthier and fresh products could be observed. Also, quality levels of fresh fruits and vegetables attracted more attention. However, quality as a concept has developed and alongside process and convenience attributes also encompassed health aspects [23]. In this context, the concept of functional food became increasingly popular. Functional foods include ingredients that provide specific health benefits in addition to their natural energy contribution [22]. Apart from serving as meals, their specific features can function e.g., as a source of micronutrients which is beneficial for human health [22,24]. Especially in Central and Northern European countries, there is an increasing acceptance of functional foods that is mainly due to change in health consciousness [25]. Functional foods often appeared in processed forms where the additional nutrients were added during the production process. Additionally, biofortified crops served as an example for natural functional food products. Here, the micronutrients were introduced during cultivation instead of processing [20]. However, while a number of trials have been conducted on the biofortification with selenium and iodine, only few products are yet available in Europe's food retail market. One exception is Finland, where the use of mineral fertilizers containing selenium became mandatory in the mid-1980s. This measure has improved the selenium supply of the Finnish population from a very poor status to a sustainably optimal level [13].

In a German consumer survey, Wortmann et al. examined if fruits like apples were preferred over food supplements as a source of selenium. As hypothesized, they found a higher acceptance for apples that are rich in selenium than for the corresponding food supplements [26]. Apples are among the most popular fruits of Germans [27]. They are also the most often cultivated crops within the fruit category in agriculture [28]. In addition, due to various food scandals in recent years, consumers had higher trust in fruits which were grown locally [29]. Selenium-rich apples were therefore seen as a suitable food alternative to provide a natural source of selenium and to reach large parts of the German population [26].

In order to inform consumers about the benefits of functional foods, producers often used authorized health claims [30]. They supported the consumer's choices by suggesting appropriate products with respect to personal needs. Moreover, health claims often served as marketing instruments because their beneficial contents added value to the original carrier products [31]. In Europe, the European Food Safety Authority (EFSA) is the institution that approves the health claims. They have established a database where all available health and nutrition claims authorized by the European Union were listed [32]. Regarding the benefits of selenium and iodine, particularly two health claims can be noted: "Selenium contributes to the normal function of the immune system" and "Iodine contributes to the normal production of thyroid hormones and normal thyroid function" [32].

To our knowledge, the German consumers' willingness to purchase biofortified apples was not examined so far. However, Wortmann et al. provided first ideas of the consumers' acceptance but they did not analyze the impact of product attributes in the framework of a purchase decision [26]. Another research project focused on consumers' willingness to pay for biofortified iodine vegetables in Africa [33]. Furthermore, consumers' motivations to consume selenium-rich foods were examined in Australia [34]. The intake of the micronutrients selenium and iodine in form of food supplements has been analyzed for German consumers [35]. In the existing literature of consumer behavior regarding apples, research focused on the influence of apple varieties and the related attributes like taste, sweetness, firmness, or crispiness [36–38]. Additionally, consumer preferences were measured analyzing the impact of quality, price, reduced pesticide input, packaging as well as organic or local origin [29,39]. In recent years, increasing attention was drawn to ecological packaging in Germany [40]. Especially plastic-free wrapping material for fresh food has become more important [41].

The findings indicated that the consumers' purchase decision on apples depended on a number of product characteristics which had to be considered next to selenium and iodine in this study.

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Previous research on processed functional foods analyzed the influence of health claims, brands, price and the base product which contains the micronutrients [25,42,43]. Contrarily, this study focused on biofortified selenium and iodine apples as a natural source of micronutrients. Factors influencing the willingness to purchase those apples were examined in a discrete choice experiment (DCE), designed as a realistic apple purchase situation.

2. Methods and Material

2.1. Data Collection and Survey Design

Data was collected via online interviews. A fully structured questionnaire was developed. The questionnaire included screening questions regarding the weekly purchase of fresh food, frequency of apple consumption, age, gender, and region. Only participants from eighteen years who consumed apples at least once a month were allowed to participate. In addition, participants were asked about their preferences for apple varieties, their present consumption of food supplements, their knowledge of micronutrients, and their attitude towards different health claims regarding the effects of selenium and iodine. Furthermore, the questionnaire included a concept description of biofortified selenium and iodine apples. The innovative apples with high contents of micronutrients were described and a picture of apple trees was shown. After the concept description, the discrete choice experiment followed. More detailed information regarding the experimental design of the DCE are provided in section 2.3. After respondents were asked to choose their preferred selenium and iodine apple product, a question including statements of further purchase motives of apples was attached. The respondents were recruited by the respondi AG who provided an online household panel for consumer research. The questionnaire was scripted using LimeSurvey software version 2.00. The collected data was prepared using the statistical software SPSS version 26 and Stata 15.1. χ^2-tests were applied to analyze the differences between male and female response behavior. Factor analysis and multinomial logistic regression were carried out for more detailed statistical analysis. Data quality checks were implemented regarding the exclusion of incomplete interviews and interviews with a very short interview length. Interviews which failed the question for the level of attention were excluded from the sample as well. Overall, n=1042 complete interviews with German consumers entered into the analysis.

2.2. Theoretical Background

Discrete choice experiments are standard method in consumer research for measuring the preferences for new food products [44]. With regard to the research objective, the consumer's tradeoff between individual levels of attributes of the innovative selenium and iodine apples in the purchase decision was analyzed. Consumers were asked to choose one apple product out of three from a set of offered alternatives. The estimated values from all choices are called utility values [45]. The framework for the analysis is called random utility theory and is based on McFadden's approach with an individual utility function for each consumer depicted in equation 1 [46–48].

$$U_{in} = V_{in} + \varepsilon_{in} \quad (1)$$

According to the random utility framework, each individual n has an unobservable utility U_{in} which consists of an explainable share V_{in} and a random component ε_{in} of utility which is associated with choice alternative i. Assuming that A is the set of all choice alternatives with J elements, then the individual n will choose option i over another option j if the following term applies:

$$U_i > U_j \; where \; i \neq j \;\; \in A \quad (2)$$

That is to say, the utility of option i is larger than the utility of option j. Equation 3 shows the probability that individual n will choose option i:

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$$P_{in} = P\left[\{\varepsilon_{jn} - \varepsilon_{in}\} < \{V_{in} - V_{jn}\}\right] for\ i \neq j \quad \in A \tag{3}$$

For the calculation of the choice probabilities, the distribution of the random component ε_{in} needs further specification based on McFadden's basic approach. Equation 4 shows the multinomial conditional logit model which is often applied in discrete choice experiments:

$$P_{in} = \frac{e^{V_{in}}}{\sum_{j=1}^{J} e^{V_{jn}}},\ j = 1, \ldots, J\ and\ j \neq i \tag{4}$$

In order to calculate the multinomial conditional logit model in this research, attributes and levels of the biofortified apples had to be determined.

2.3. Design of the Discrete Choice Experiment

From the outside, biofortified apples do not differ from other apples. In order to demonstrate their specifics, packed apples were chosen over lose ones in the DCE. For the illustration in the online questionnaire, realistic apple products were created. They represented ordinary apple products that were available in German supermarkets in June 2019 before the survey was conducted. Thereby, the focus of the respondents was not directly pointed at the micronutrients but on the apple product as a whole. The following hypothesis were tested in this study:

H1: The combination of iodine and selenium is the most preferred micronutrient supply

H1 describes the assumption that both micronutrients in combination offer higher value to the consumers than individual micronutrients. In order to provide the consumers with basic background knowledge of the benefits of biofortified apples, the health claims "Contributes to the normal function of the immune system" and "Contributes to the normal production of thyroid hormones and normal thyroid function" were used [32]. Previous research findings indicate that the normal functioning of the immune system is a well-accepted health claim by German consumers [26]. Hence, we hypothesized:

H2: "Contributes to a normal functioning of the immune system" is the preferred health-related slogan

Previous research regarding the choice of apples has shown that varieties played an important role for consumers in the purchase decision. Varieties are associated with e.g. the preferred taste and had a positive effect on the choice of apples. Especially club apples like Pink Lady® became more important [49]. The third hypothesis was formulated as follows:

H3: The variety Pink Lady® has the highest impact on the choice of apple products

Due to increasing consciousness for sustainable purchasing behaviour, consumers pay more and more attention to consequences of their shopping behaviour. By choosing plastic-free packaging material, an increasing consumer segment contributes to the reduction of microplastics [40]. Also, the general reduction of waste and efforts that were required for recycling packaging material are coming to the fore [41]. For this reason, it was assumed that consumers prefer sustainable packaging material for apples. Consequently, the fourth hypothesis adressed the packaging material:

H4: The plastic-free alternative is the most preferred packaging material

With regard to target groups for the new apples, the segment of buyers of food supplements was identified [26]. The group revealed a higher acceptance for biofortified apples mainly because they were familiar with food supplements to obtain particular micronutrients. For this reason, the fifth hypothesis addressed potential groups of buyers.

H5: Consumers of food supplements have a higher acceptance of biofortified apples

For the DCE, the attributes packaging, health-related slogan, variety, "Rich in" (selenium/iodine), and price were selected (Table 1). The information regarding the biofortified

apples were listed in form of health-related slogans promoting the beneficial effects of these innovative apples. A new brand name for a selenium-biofortified apple Selstar® was included. The price levels based on market observations in supermarkets. Overall, the discrete choice experiment consisted of five attributes with three respectively four levels.

Table 1. Attributes and levels of the discrete choice experiment

Attributes	Levels
Packaging[1]	Cardboard foodtainer, banderoles, no print
	Plastic bowl, plastic foil
	Foodtainer, hardcover slipcase, color print
Health-related slogan	Tasty and healthy enjoyment
	Naturally with micronutrients
	Contributes to a normal functioning of the immune system
	Contributes to a normal thyroid functioning
Variety/brand	Elstar
	Braeburn
	Pink Lady®
	Selstar®
Rich in	Selenium
	Iodine
	Selenium and iodine
	No micronutrients stated on the choice set
Price	2.29 €
	2.49 €
	2.99 €
	3.49 €

[1] The packaging was not rotated, i.e. remained in the same order.

Regarding the different formats of packaging, pictures were shown to the respondents in the online questionnaire. This supported the visual imagination of the new apple products (compare Figure 1). The ideas for the packaging were generated via market observations and reflected the most common types. Since the packaging constituted the outer appearance of the innovative apples, it also had an impact on the initial impression of the potential consumers. For that reason, three types of packaging were used as labels (fixed label design) in the DCE and therefore did not vary on the set cards. Packaging A was comprised of plain cardboard without imprints which partly covered the apples. Packaging B was a plastic bowl with transparent plastic foil where the apples were completely covered but visible through the foil. Packaging C was comprised of color printed cardboard which covered most of the fruits. Below the pictures of the packaging was a banner including the health-related slogans. The prices were declared in Euros and referred to the entire product unit. Overall, the different apple products were always shown as version A, B, and C in one choice set with fixed ordering of packaging and varying health-related slogans, varieties/brands, micronutrients, and prices. Before the respondents were asked to make a choice from the displayed choice sets, the concept of the innovative apples was introduced at the beginning. The description was developed according to merchantable commercial material. It described briefly the presence of both micronutrients and their benefits. The following text was shown to the respondents:

In the next section, we would like to introduce to you a new kind of apple which is especially rich in selenium and iodine. Selenium and iodine are essential micronutrients which contribute significantly to the improvement of human health.

The first companies are currently launching the new apples in retail. Please imagine you are in a supermarket and would like to purchase a package of 6 apples. Which of the following apples would you choose?

Overall, twenty choice sets were developed. Figure 1 shows one example of a choice set.

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Version	A	B	C
	 Contributes to a normal thyroid functioning	 Naturally with micronutrients	 Contributes to a normal functioning of the immune system
Variety/brand	Elstar	Selstar	Braeburn
Rich in	Selenium & Iodine	Selenium	/
Price	2.29 €	2.29 €	3.49 €

Figure 1. Example of one choice set card with three choices A-C out of a total of twenty set cards with different choice alternatives.

In order to minimize the number of decisions in the online interview, the number of choice sets was reduced with the Sofware Ngene version 1.2 [50]. Consequently, each respondent was shown one choice set and only had to pick one out of three offered alternatives for apple products. Herewith, an overload of choices which often caused fatigue in the response behavior was avoided. Due to the rather large sample size of n=1042 interviews, sufficient choices were recorded for robust statistical analysis. The specific set up of this choice experiment did not allow variation of product attributes and levels without restrictions. Exclusions of attributes and levels were done according to potential market constraints and logic. The following exclusions were considered: Naturally with micronutrients and no micronutrients, contributes to a normal functioning of the immune system and no micronutrients, contributes to a normal thyroid functioning and no micronutrients; 2.29 € and selenium & iodine; 3.49 € and no micronutrients; Selstar® and no micronutrients.

Equation 5 describes the estimated multinomial logit model of the statistical analysis. All experimental variables were included as well as the interactions terms of the micronutrients and the packaging, the interaction of selenium and iodine with food supplements and packaging, and the interaction of selenium and iodine with further motivations for purchasing the innovative apples and packaging. These motivations were measures via statements and condensed by means of factor analysis (section 2.3) beforehand.

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$$
\begin{aligned}
V = {} & \beta_1 * \text{constant cardboard} + \beta_2 * \text{constant color print} + \beta_3 * \text{price cardboard} + \beta_4 * \text{price plastic} + \beta_5 \\
& * \text{price color print} + \beta_6 * \text{Pink Lady®} + \beta_7 * \text{Elstar} + \beta_8 * \text{Braeburn} + \beta_9 \\
& * \text{Contributes to a normal functioning of the immune system} + \beta_{10} \\
& * \text{Tasty and healthy enjoyment} + \beta_{11} * \text{Naturally with micronutrients} + \beta_{12} \\
& * \text{Selenium x cardboard} + \beta_{13} * \text{Selenium x plastic} + \beta_{14} * \text{Selenium x color print} + \beta_{15} \\
& * \text{Iodine x cardboard} + \beta_{16} * \text{Iodine x plastic} + \beta_{17} * \text{Iodine x color print} + \beta_{18} \\
& * \text{selenium \& iodine x cardboard} + \beta_{19} * \text{selenium \& iodine x plastic} + \beta_{20} \\
& * \text{selenium \& iodine x color print} + \beta_{21} \\
& * \text{selenium \& iodine x food supplement x cardboard} + \beta_{22} \\
& * \text{selenium \& iodine x food supplements x plastic} + \beta_{23} \\
& * \text{selenium \& iodine x food supplements x color print} + \beta_{24} \\
& * \text{selenium \& iodine x information requirement x cardboard} + \beta_{25} \\
& * \text{selenium \& iodine x practicability x cardboard} + \beta_{26} \\
& * \text{selenium \& iodine x sustainability x cardboard} + \beta_{27} \\
& * \text{selenium \& iodine x information requirement x plastic} + \beta_{28} \\
& * \text{selenium \& iodine x practicability x plastic} + \beta_{29} \\
& * \text{selenium \& iodine x sustainability x plastic} + \beta_{30} \\
& * \text{selenium \& iodine x information requirement x color print} + \beta_{31} \\
& * \text{selenium \& iodine x practicability x color print} + \beta_{32} \\
& * \text{selenium \& iodine x sustainability x color print}
\end{aligned} \tag{5}
$$

2.4. Factor Analysis

Factor analysis was applied in order to examine further purchase motivations of apple products which where integrated into the multinomial conditional logit model (equation 5). It is a common method applied in marketing research for the purpose of discovering invisible components that affect consumers' decisions. Steptoe et al. extracted nine factors as basic motives for selecting food. Among them were convenience, sensory-appeal, natural content, familiarity, or similar motivations [51]. A question regarding motives for purchasing biofortified apples was developed for this research as well. Pre-formulated items and interval-scaled responses were included in the questionnaire. The respondents were asked to rate statements on a 5-point Likert-scale which ranged from "Is very appealing to me" to "Is not appealing to me at all". The terms were formulated as additional benefits of the innovative apples and reasons for purchasing them. Included were descriptions regarding origin of the apples, sensory-appeal of the fruits, packaging specifics, and information regarding the production. Interviews including missing values were excluded from the factor analysis. The extracted factors were included in the discrete choice model.

3. Results

3.1. Sample Description and Socio-demographic Criteria

After data preparation and quality checks, the final sample included a balanced distribution of gender with 51.4% female and 48.6% male respondents as displayed in Table 2. About one third of the respondents were older than 54 years (32.0%) and most of them lived in the densely populated Western part of Germany (35.4%) followed by the South with 27.6%. Regarding the respondents' occupation, more than half were employed full-time (56.5%) followed by 13.4% part-time and 12.1% were retired. Generally, the level of employment was rather high. Regarding the educational level,

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35.7% held a university degree. Considering household size, most interviewees lived in a household with two people (38.2%) and 27.8% lived in a single household. Only very few respondents lived in households with five or more people. 19.0% of all respondents had children under twelve years.

Table 2. Characteristics of survey participants and social-demographic criteria

Characteristic	Unit	Respondents	
		n	%
Total		1042	100
Gender	Female	536	51.4
	Male	506	48.6
Age	18-24 years	97	9.3
	25-34 years	195	18.7
	35-44 years	173	16.6
	45-54 years	244	23.4
	>54 years	333	32.0
Region	West	369	35.4
	South	288	27.6
	North	193	18.5
	East	192	18.4
Occupation	Full-time employed	589	56.5
	Part-time employed	140	13.4
	Retired	126	12.1
	Student	74	7.1
	Homemaker	44	4.2
	Unemployed	38	3.7
	Practical education	14	1.3
	School	7	0.7
Education	University degree	372	35.7
	Secondary school	277	26.6
	High school diploma	206	19.8
	Elementary school (Hauptschule)	104	10.0
	Specialist/ master craftsman	76	7.3
	Still attending school	4	0.4
Size of the household	1 Person	290	27.8
	2 Persons	398	38.2
	3 Persons	174	16.7
	4 Persons	127	12.2
	5 Persons	37	3.6
	More than 5 Persons	16	1.5
Parenthood	No children	548	52.6
	Children under twelve years[1]	198	19.0

3.2. Consumption Habits of Apples and Food Supplements

About a quarter of the respondents (24.1%) eat apples on a daily basis and another 34.5% consume apples several times a week. Overall, apples are part of the regular diet for most of the respondents and only a minor segment 8.0% of the respondents indicated to eat apples only rarely. However, it must be noted that apple consumption was a mandatory screening criterion so that only people who eat apples at least sometimes were considered for the survey. In the older age groups, there was a larger share of respondents who eat apples on a daily basis. 32.4% of consumers who

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were older than 54 years eat apples daily compared to 14.4% of consumers aged 18-24 years. For the varieties the results show that Pink Lady® was mentioned as the most often purchased variety with a share of 23.8% (Table 3). It was also the most often purchased variety by women with 25.9% and men with 21.5%. Braeburn ranked second with 12.6% of all mentions. However, looking at the differences between men and women, it can be noted that whereas women ranked Braeburn second with 14.4%, Golden Delicious was the second most often purchased variety by men with 14.7%. Only 10.7% of men chose Braeburn as their most often purchased variety. Therefore, in the case of Braeburn, a difference in the purchasing behavior between men and women was recorded. The third most often purchased variety was Elstar with 12.0% of all mentions and 11.0% of men and 13.1% of women. As depicted in Table 3, Pink Lady®, Braeburn, and Elstar accounted as most often purchased varieties for 48.4% of the German consumers.

Table 3. Most often purchased apple varieties of German consumers by gender

Varieties	Total[1]		Male		Female	
	n	%	n	%	n	%
Pink Lady®	239	23.8	104	21.5	135	25.9
Braeburn	127	12.6	52	10.7	75	14.4
Elstar	121	12.0	53	11.0	68	13.1
Golden Delicious	103	10.3	71	14.7	32	6.1
Jonagold	94	9.4	47	9.7	47	9.0
Granny Smith	68	6.8	32	6.6	36	6.9
Boskoop	61	6.8	29	6.0	32	6.1
Gala	40	4.0	20	4.1	20	3.8
Red Delicious	37	3.7	21	4.3	16	3.1

χ^2: p=0.002; 1 n=1005; only varieties with more than 3.0% of mentions are displayed

Regarding the knowledge about the two micronutrients iodine and selenium, consumers were asked to choose only those micronutrients from a list which they have heard of before. Generally, the overall awareness of iodine (71.3%) was much higher than the awareness of selenium (46.9%) (see Table 4). Furthermore, there was a difference in the awareness of the two micronutrients between men and women. 76.3% of all women were aware of iodine and in contrast 66.0% of all male respondents had ever heard about iodine (χ^2: $p \leq 0.001$). In the case of selenium, the female share was 51.9% and the share of men was only 41.7% (χ^2: p=0.001). In addition, the respondents were asked to choose those micronutrients from a list which they had previously consumed in form of food supplements. A difference in the consumption between selenium and iodine was found. 19.3% of all respondents had consumed iodine in form of food supplements and 12.5% had consumed selenium in form of food supplements.

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Table 4. Knowledge of selenium and iodine as well as consumption as food supplement by gender

Micronutrients	Status	Total		Male		Female	
		n	%	n	%	n	%
Iodine* **	Stated awareness	743	71.3	334	66.0	409	76.3
	Unaware	299	28.7	172	34.0	127	23.7
Selenium* **	Stated awareness	489	46.9	211	41.7	278	51.9
	Unaware	553	53.1	295	58.3	258	48.1
Iodine as	Consumers	201	19.3	86	17.0	115	21.5
food supplement (n.s.)	Non-consumers	841	80.7	420	83.0	421	78.5
Selenium as	Consumers	130	12.5	42	8.3	88	16.4
food supplement* **	Non-consumers	912	87.5	464	91.7	448	83.6

χ^2: ***p ≤ 0.001; **p ≤ 0.01, *p ≤ 0.05, n.s. p ≥0.05

In the consumption patterns, a difference between men and women could be observed. 21.5% of the women declared that they had consumed iodine as food supplement compared to 17.0% of men. However, the difference was not significant (χ^2: p=0.068). In the case of selenium, the difference was significant and higher with 16.4% of women who had consumed selenium as food supplement and 8.3% of men (χ^2: p=0.000). Hence, iodine was the more common micronutrient and it was also more often consumed as food supplement than selenium. Additionally, women were more often aware of both micronutrients and consumed both of them more often in form of food supplements.

3.3. Results of the Factor Analysis

Only items with factor loadings with values larger than 0.5 were displayed (Table 5). The extracted factors explained 59.1% of the variation and were allocated to three different factors. Therefore, it was assumed that the extracted components contributed well to explaining the measured variance of the purchase motives of the innovative apples.

Table 5. Rotated component matrix of principal component analysis and allocation to factors

Factors	Statements	Factor Loadings	
Sustainability	Produced in Germany	0.84	
	Produced locally/nearby	0.82	
	Organically grown	0.72	
	Freshly picked and crispy	0.69	
	Plastic-free packaging	0.66	
	Intense fruity taste	0.65	
	Integrated production	0.52	
Practicability	Warranty of long shelf life fruits	0.72	
	Intense red fruit peel	0.70	
	Aesthetically appealing packaging	0.69	
	Easy to open	0.65	
	Handy, medium fruit size	0.57	
	Popular apple variety 'Elstar'	0.52	
Information requirements	Especially suitable for vegetarians or vegans		0.78
	Imprint: Certified by University Medical Center Charité Berlin		0.71
	Further information available in the internet, e.g. via QR code		0.70
	Especially suitable for low allergy nutrition		0.68

KMO-criterion: 0.914

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The three extracted factors can be described as follows:

Factor 1: It was called **sustainability** because it encompassed regional, seasonal, and freshness aspects of the apples. It consisted of statements with high factor loadings addressing the country of origin Germany and the region of production of the apples which was close to the respondents' homes. Also, it included a statement regarding organic cultivation. Moreover, the time of harvest loads highly on this factor as well as the statement regarding the plastic-free packaging material. Intense fruity taste and integrated production are the last two terms that loaded on the first component.

Factor 2: It was called **practicability** and included ideas regarding a long shelf life, intense red fruit husk and an aesthetically appealing packaging. In addition, the statement regarding the easy opening of the packaging loaded highly on this factor. Finally, the statement regarding the well-known and third most often purchased variety 'Elstar' loads highly on this factor. It is called practicability because mainly items regarding reduced efforts in the handling of apples and simplifying choice loaded on this factor.

Factor 3: It was called **information requirement** and comprised additional information regarding suitability for vegan and vegetarian nutrition. Also, the certification of the University Medical Center Charité Berlin loaded highly on this factor. One term regarding the availability of further information on the internet and the information regarding the suitability for low allergies nutrition was included in this factor, too. Generally, the factor comprised ideas regarding specific information and safety and spent details on the product.

3.4 Results of the Discrete Choice Analysis

In the DCE-model most of the analyzed parameters revealed positive effects on the apples choice except for the price which exerted a negative effect. However, the intensity of the effects differed considerably (Table 6). For the micronutrients, findings showed that selenium did not have a significant effect on the willingness to purchase apples. None of the coefficients of the interaction terms of selenium and the packaging were significant. Contrarily, the interaction coefficient of iodine and the cardboard packaging (0.64*) as well as iodine and the plastic container (0.68*) were significant whereas only the coefficient of the color print packaging was not significant. However, the interaction of both micronutrients and the color print packaging had a significant positive effect. Remarkably, the coefficient was 0.73* and had a higher effect than in the case of the interaction of iodine and the other two packaging variants. With the color print packaging the combination of both micronutrients had a stronger effect than each micronutrient individually.

Table 6. Results of the Multinomial Conditional Logit Model

	β coefficients	Standard Error
Constants		
Constant cardboard	2.01*	0.96
Constant color print	0.22	1.02
Interaction terms micronutrients and packaging		
Selenium x cardboard	0.05	0.37
Selenium x plastic	0.13	0.27
Selenium x color print	0.23	0.24
Iodine x cardboard	0.64*	0.25
Iodine x plastic	0.68*	0.29
Iodine x color print	0.21	0.29
Selenium & iodine x cardboard	0.48	0.29
Selenium & iodine x plastic	0.48	0.28

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Selenium & iodine x color print	0.73*	0.32
Nutrition and health claims		
Contributes to a normal functioning of the immune system	0.80***	0.17
Tasty and healthy enjoyment	0.51***	0.14
Naturally with micronutrients	0.54**	0.16
Varieties		
Pink Lady®	0.60***	0.14
Elstar	0.40**	0.14
Braeburn	0.21	0.14
Interaction terms micronutrients, purchase motives, and cardboard packaging		
Selenium & iodine x information requirement x cardboard	0.45**	0.16
Selenium & iodine x practicability x cardboard	0.13	0.14
Selenium & iodine x sustainability x cardboard	0.64***	0.16
Interaction terms micronutrients, purchase motives, and plastic packaging		
Selenium & iodine x information requirement x plastic	0.25	0.14
Selenium & iodine x practicability x plastic	0.16	0.15
Selenium & iodine x sustainability x plastic	-0.38**	0.14
Interaction terms micronutrients, purchase motives, and color print		
Selenium & iodine x information requirement x color print	-0.10	0.15
Selenium & iodine x practicability x color print	0.09	0.15
Selenium & iodine x sustainability x color print	0.13	0.15
Interaction terms micronutrients, food supplements, and packaging		
Selenium & iodine x food supplement x cardboard	-0.12	0.31
Selenium & iodine x food supplements x plastic	-0.06	0.33
Selenium & iodine x food supplements x color print	0.50	0.35
Price		
Price cardboard	-1.16***	0.24
Price plastic	-0.68**	0.21
Price color print	-0.65**	0.21

Pseudo R^2: 0.11; Significance level ***p ≤ 0.001; **p ≤ 0.01, *p ≤ 0.05

The results also showed that the health claim regarding the normal functioning of the immune system had the strongest impact (0.80***) on the willingness to purchase the new apples. The slogans "Tasty and healthy enjoyment" (0.51***) and "Naturally with micronutrients" (0.54**) were significant and positive as well. Concerning the varieties, Pink Lady® (0.60***) and Elstar (0.40**) both had a significant and positive effect whereas neither Braeburn nor Selstar® showed such effect. The interaction term of both micronutrients, cardboard container, and information requirement was 0.45** and had a significant positive effect. However, the effect of the interaction of both micronutrients, cardboard container and sustainability was stronger with a positive and significant coefficient of 0.64***. In the interaction of both micronutrients, plastic packaging, and purchase motives, there was only one statistically significant negative coefficient of -0.38** in the case of sustainability. Color print packaging, both micronutrients and purchase motives did not show significant coefficients. The interaction terms of both micronutrients, the consumption of selenium and iodine as food supplements, and the packaging did not have any effects either. In contrast to all the other variables, the price had consistently a statistically negative effect on the willingness to purchase for all packaging formats. The strongest negative effect of the price was measured for the

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cardboard packaging with a coefficient of -1.16***, followed by -0.68** in the case of plastic, and -0.65** in the case of the color print.

4. Discussion

4.1 Influence of Presence of Selenium and Iodine

In the DCE, the micronutrient selenium alone did not have a significant effect on the willingness to purchase apples. One explanation for this could be the limited knowledge about selenium. Only 46.9% of the respondents had ever heard of selenium (Table 4). Considering the effect of iodine alone, the results of the discrete choice model turned out to be significant and positive. The consumers were more familiar with this micronutrient (71.3%). Also, due to established functional foods like iodized salt, the insufficient supply of iodine as well as the presence of iodized food products in Germany was more commonly known [52]. That means that the majority of the respondents was also aware of the relevance of iodine for human health. The combination of both micronutrients affected the willingness to purchase the color print positively. Likewise, the effect here had the highest coefficient. On the one hand, this effect could be caused by the positive effects of iodine. On the other hand, this effect could also be carried by the assumption that the positive effect of iodine for the health is reinforced by the presence of selenium. Possibly, the lack of knowledge about selenium and its positive effects on human health were counterproductive in the decision making process. Hypothesis 1 addressed that the combination of both micronutrient was the preferred supply. Thus, this hypothesis can be confirmed by this research when the color print product is considered. In order to promote the micronutrient selenium, further details about selenium deficiencies and its health benefits need to be provided with the biofortified apples. Preferences for special product types (color print) should be considered.

4.2 Influence of Health-related Slogans

The health-related slogans encompassed four different levels including two authorized health claims. The latter explained the benefits of selenium and iodine. The other two levels addressed in addition to health aspects the taste of the new apples and the natural content of micronutrients, respectively. The combinations were chosen because previous research has shown that physiological health claims would be valued more if they were combined with a healthy carrier [42]. In agreement with this, the present results confirm a positive effect of health-related slogans on the willingness to purchase biofortified apples. The results were thus also in line with previous studies which examined the importance of health claims in processed functional foods [25,31,53,54]. In the case of selenium and iodine apples, consumers had a positive attitude towards the health claim regarding the normal functioning of the immune system. On the contrary, the second health claim regarding normal thyroid function did not have a positive effect on the willingness to purchase. Furthermore, the slogans addressing the taste and the natural content of micronutrients of the apples had positive effects. Consequently, hypothesis 2 can be confirmed by this research because the health claim concerning the normal functioning of the immune system had the strongest effect on the willingness to purchase the new apples. It can be noted that background information about the innovative aspects of the new apples offered additional benefits for the consumers.

4.3 Influence of Variety and Brand Name

In previous apple choice experiments conducted by Yue and Tong, varieties were associated with specific product characteristics such as taste or texture and were recognized by the consumers [38]. Since apple tastings could not be provided in our online approach, two varieties and two brand names for apples were included. Elstar and Braeburn were among the most often purchased apple varieties in Germany (Table 3). Pink Lady® was the most often purchased variety by 23.8% of the respondents. Since there had not been a comparable selenium- or iodine-rich apple in German retail before, a brand name for the innovative apple was included as well. It was called Selstar® and was shown to the consumers in the discrete choice experiment for the first time [55]. The results showed

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that the two most common varieties Pink Lady® and Elstar had positive effects on the willingness to purchase the innovative apples. This was in line with previous research findings where variety had a positive effect and price a negative effect on the willingness to purchase apples [38,56]. That means concerning variety, the German consumers acted as expected. Looking at the brand name Selstar® which represented a new name for selenium-rich apples, no effects on the willingness to purchase were found. Keeping in mind that the respondents had only just learned about the innovative biofortified apples and this new brand name, the finding was not surprising. Since none of the consumers had ever heard of the name Selstar® nor seen it in German retail, none of the respondents could refer to a reference of this product. Among the three well established apple varieties and brands in the German market, the new name was not recognized. Hypothesis 3 can be confirmed by the research because the most common variety Pink Lady® had the strongest effect among the varieties or brand names.

4.4 Influence of Purchase Motives

The increased consciousness for sustainability in food markets was supposed to have a positive effect on the willingness to purchase in the DCE if the factor sustainability interacted with the cardboard material and both jointly displayed micronutrients (0,64***) and a negative effect if interacted with plastic packaging. These findings are in line with current research findings regarding a negative attitude of consumers towards plastic packaging (-0,38**). Recently, even a trend towards zero-packaging material could be observed. The prohibition of plastic bags in German retail was one example of the recent political decisions [57]. Consequently, the traditional plastic packaging did not have positive effects on the willingness to purchase the new apples. Apart from that, positive effects of the interaction of both micronutrients, the factor information requirement and the cardboard packaging also reflected a recent trend in consumer behavior in Germany. With regard to production and processing methods and origin of food, consumers have become increasingly concerned [58]. For that reason, producers had increased their attempts to provide more detailed information regarding the supply and production chains of their products. In that manner, they have tried to overcome mistrust on the consumers' side. Also, consumers tended to decide in favor of locally produced food products as they assumed a higher food safety [58]. The factor practicability on the contrary did not have a significant effect on the willingness to purchase the innovative apples, regardless of the packaging material. It seemed that the benefits of easy handling and little efforts did not matter to a larger extent. However, sustainability and information requirements showed positive effects. A tendency towards more critical reflection of product information and environmentally friendly packaging material could be observed. Hypothesis 4 comprising plastic-free packaging material as preferred packaging can be confirmed by this research.

4.5 Influence of Consumption of Food Supplements

Previous research demonstrated that the consumption of food supplements had increased in recent years [35]. For a lot of people, food supplements settled in the regular nutrition and from the perspective of elderly people they were considered as important as prescribed medicine for the health [59]. In this research, 19.3% of the respondents mentioned that they had consumed iodine as food supplement and 12.5% selenium. However, the idea that these consumers would be more attracted to the biofortified apples stated in hypothesis 5 could not be verified. The interactions of both micronutrients, consumption of food supplements, and the packaging did not have significant effects. One possible explanation could be that the consumers of food supplements were already provided with sufficient micronutrients. Therefore, they did not see the necessity to consume the micronutrients in form of apples. However, they did not consider the biofortified selenium and iodine apples as equivalent to food supplements. Another explanation could be that the apples were still unknown and consumers were not adequately convinced by the information provided in the questionnaire.

4.6 Influence of Price

The product price was included in the experiment to give consumers an indication of the costs they would have to spend for the new apples. The price steps were chosen based on market observations in German retail for similar apple products. It was assumed that price had a negative impact on the willingness to purchase apples [29]. This was confirmed by the results of the DCE and the negative influence of price on the willingness to purchase apples as well.

4.7 Limitations of the Present Study and Implications for Further Research

Overall, the research approach implied the following limitations. The brand name Selstar was included in the choice sets but the consumer had never heard of it. No explanation was given beforehand. The pictures of the packaging were supposed to support the visual imagination of the product. However, they contained different colored apples which could have influenced the respondents. Furthermore, the choice experiment aimed at creating a decision situation which was close to the shopping reality in German supermarkets. Nevertheless, the respondents were not aware of reference products from real supermarkets because the new apples were still at the developing stage.

5. Conclusions

Considering the isolated effect of the micronutrient selenium, it was assumed that the benefits derived from the supply of selenium were not sufficiently communicated yet. If selenium and iodine biofortified apples shall serve as regular, natural selenium and iodine source for vast parts of the German population, the benefits of the consumption need to become more obvious to all consumers in the future. The intensification of marketing at the point-of-sale could be one solution for that. More information about the consequences of insufficient supply with selenium on human health could be provided in order to increase the awareness for health problems that result from constant deficiencies. Generally, it should become more visible to the German population which health damages could occur if the insufficient supply of these two essential micronutrients continued. Apart from that, consumers purchase decisions are influenced by a set of product attributes. Common varieties and appropriate prices are crucial for the purchase decision. However, given sufficient background information, the results suggest that micronutrient attributes too can positively influence purchase decisions on apples. Micronutrients, especially those with limited awareness like selenium should be combined with more well-known examples like iodine, health-related slogans, and relevant marketing attributes.

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