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University of Kassel,
Nordbahnhofstrasse 1a,
D- 37213 Witzenhausen,
Germany.

Email: *editorialboard@fofj.org*



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# Editorial

## An Impact of COVID-19 Pandemic on The Global Food Security and Nutrition around

**Dr. Tamara Al-jallad** works as the Head of the livestock department at the General commission for scientific Agricultural Research. Dr Al-jallad holds a PhD from Tishreen University, Syria, for a dissertation on" Serological and Molecular Study of Some Infectious Bronchitis Virus (IBV) Strains Isolated from flocks of Chickens in Syria".

*The COVID-19 pandemic had a significant threat to public health around the world.* It has had a massive impact on food security and nutrition since its onset in late 2019. Several studies have addressed the global impact of COVID-19 on food security (Sitko et al, 2022; FAO, 2021a-f; HLPE, 2020a; HLPE, 2020b).

Food security is based on four pillars: access, availability, utilization, and stability. the COVID-19 crisis adversely affects all the pillars of food security through its impact on household income and food markets. The State of Food Security and Nutrition in the World (2021), which is an annual flagship report jointly prepared by FAO, IFAD, UNICEF, WFP and WHO, estimated the number of people in facing hunger around the world. Data showed that this number reached between 720 and 811 million in 2020. This represents an increase of between 118 and 161 million more people who were facing hunger in 2020 than in 2019 (FAO et a, 2021).

Balanced nutrition is vital in maintaining immune homeostasis and resistance to disease, including infections with viral pathogens.

Moreover, a person's nutritional status can modulate infectious disease and the inflammatory processes associated with it positively or negatively by altering the immune system (Rodriguez-Leyva and Pierce, 2021). The body's confrontation against this Covid-19 requires paying serious attention to the quality of consumed food, exercising and getting enough hours of sleep, which leads to a good immune status.

Under the COVID-19 pandemic, food systems have suffered from a noticeable crisis, threatening people's accessibility to food due to low income and high prices of some foods. Moreover, the world has observed a significant disruption to food supply chains in the wake of lockdowns triggered by the global health crisis. Therefore, the lockdowns intended to contain the disease led eventually to increasing hunger. The country's economic status had an influence on the outcomes of the alterations in food accessibility that occurred globally. More severe implications were observed in the developing countries due to delays in

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food distribution, loss of food quality and quantity, impairments in food accessibility and losses of income to purchase food.

In addition, the social isolation most have experienced during the COVID-19 pandemic led to a change in eating behaviour which had a negative impact not only on nutritional status but also on general well-being. This may cause a long-term adverse effect on the population's health.

Another impact of the pandemic is the impact on the elderly. Malnutrition in the elderly makes them more susceptible to COVID-19 infections.

Malnutrition sustained for long periods will lead to increased plasma risk factors for cardiovascular disease, diabetes and cancer (Rodriguez-Leyva and Pierce, 2021).

It was clear that the global systems were in shock when the outbreak began, which led to all the mentioned impacts on nutrition, food security and public health. However, after two years of fighting against this pandemic, the countries started to find their way back to normal and hopefully be prepared for any unexpected future crisis.

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# Profiling Tunisian olive oil Consumers based on the Environmental Sustainability value perception

EMNA OUERTANI [1,2*], MOHAMED ZIED DHRAIEF [2]

[1] Higher School of Agriculture, Mograne (ESAM), University of Carthage, Tunis, Tunisia
[2] Rural Economics Laboratory, National Agronomic Research Institute of Tunisia (INRAT), University of Carthage, Tunis, Tunisia

* Corresponding author: ouertaniemna2015@gmail.com

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Cluster analysis, consumption values, environmental sustainability, logistic regression, olive oil

Several research papers about olive oil consumption behaviour are based on quality attributes and indicators. Consumption values have not been explored, especially for olive oil consumption. This study provides an analysis of the Tunisian consumer's behaviour toward olive oil, based on consumption values, especially environmental sustainability value since olive oil is typically a sustainable product. Based on a survey of a Tunisian household sample, an exploratory factor analysis reveals nine dimensions among olive oil consumption values. The main factor is "Environmental sustainability value". A cluster analysis was performed exploring these nine constructs of consumer values. It revealed three consumers groups. A group with about 25% of the sample represents consumers with environmental sustainability concerns. In addition, to evaluate the impact of consumers' values on olive oil purchase decisions, a binomial logistic regression is proposed. It revealed that "Environmental sustainability value" has a positive and statistically significant impact on olive oil purchase.

## 1. Introduction

The olive crop is deeply rooted in the traditions of Tunisia, both in terms of production and consumption. Olive oil sector pruning, picking, transportation, grinding, storage, sale, etc.), has a significant socio-economic weight (IOC, 2017). Tunisian olive oil sector generates 50 million working days/ year and contributes up to 5% of Tunisia's agricultural added value. It involves more than 309 000 farmers, with orchards covering one-third of the country's crop area (1.68 million hectares of olive plantations) including 40% in organic mode, with some certification of origin (Clodoveo et al., 2021; IOC, 2017). Olive farming is characterized by an extensive, rain-fed system, with low inputs and high labour use (IOC, 2017). Tunisian olive oil is a typical example of a sustainable product, with positive social, environmental, and ethical attributes (Luchs et al., 2010).

Domestic consumption of olive oil in Tunisia is based on family reserves, direct supply of olive mills, or the use of informal circuits. Estimating olive oil consumption is difficult due to the different practices and purchasing channels. Domestic consumption is not only varying from 20.000 to 60.000 tons/year but also decreasing. While olive oil consumption has improved in most consuming countries, Tunisia has seen a drop in olive oil consumption from 6 kg/capita/year before 2000 to approximately 3.5-4 kg/capita/year in 2015. Tunisian consumption is less than the average for producing countries (20 kg/capita/year in Greece; 12

kg/capita/year in Spain and Italy) (Karray et al., 2015; IOC, 2017).

This low and declining consumption was due to the marginal actions to promote olive oil trade and consumption in the local market. The focus of the promotion is on overseas markets. In addition, the government sets prices for other vegetable oils and strengthens local refining, packaging, and trading of vegetable oils such as sunflower oil and corn oil. However, olive oil can be five times more expensive than other vegetable oils (IOC, 2017).

The ratio of olive oil domestic consumption to Tunisian olive oil production is about 20%, against 150 % in Italy, 70 % in Greece, and 40 % in Spain (Karray et al., 2015). Moreover, Tunisian consumers traditionally buy olive oil in bulk and directly from neighbouring olive oil processing units. Small quantities are sold in bottles, especially in supermarkets and hypermarkets in big cities (Mtimet et al., 2013).

Moreover, Tunisia's olive oil sector can be determined to be unsustainable, as is the entire agricultural food system. It faces several challenges:

- Environmental dilemmas consist of natural resources exhaustion, emissions into water, air, and soil, and large amounts of mills waste, etc. (Souliman et al., 2017; Erraach et al., 2021).

- Social challenges involve equity, fairness in the distribution of economic value, tradition and culture preservation, employment, working conditions, and remuneration (Erraach et al., 2021).

- Economic concerns require financial continuity, economic and regional development, and maximizing added value

- Economic concerns entail financial viability, economic and territorial development, maximization, and fair distribution of added value. (Erraach et al., 2021; Lombardo et al., 2021)

So, to promote simultaneously the three dimensions of sustainability (environmental, social, and economic), sustainable food labels and certificates were developed in the Tunisian olive oil sector such as organic certificates and geographical indications (Monastir and Teboursouk olive oil) (Clodoveo et al., 2021). These labels can improve sustainable practices within olive oil producers. They are also a basis for marketing strategies if they are well communicated to consumers and if they are really preferred by a market segment. In fact, sustainability labels can inform consumers about products that are cost-effective, socially responsible, and/or eco-friendly (Erraach et al., 2021).

To achieve sustainability goals, improve consumption in the local market, and meet consumers' requirements, especially in terms of sustainability, it is becoming evident for the Tunisian olive oil suppliers and for policymakers to adopt marketing strategies based on client preferences. Therefore, this paper aims to understand how consumption values and especially environmental sustainability values affect olive oil consumption in the Tunisian market and to propose a consumers profiling based on it.

To determine the impact of consumption values, especially environmental sustainability, on Tunisian consumer behaviour towards olive oil, section 2 develops the literature review about sustainable consumption behaviour through an exploration of consumption theories and consumption values. Section 3 defines the research methodological approach. Finally, section 4 presents and discusses the derived findings and section 5 presents the limitations and implications of the research.

## 2. Literature review

### 2.1. Theoretical context

To clarify sustainable consumption behaviour, different models have been developed, such as the Theories of Reasoned Action and of Planned Behaviour (Lombardi et al., 2017). The theory of consumption values highlights the importance of consumption values in predicting consumer choice. Several studies have revealed the usefulness of this theory to investigate consumers choice behaviour. Concerning green choice behaviour, Lin and Huang (2012) used this theory to study the decisive factors on consumer choice behaviour for green products. Biswas and Roy (2015a, 2015b) also used this theory to explore the impact of consumption values on sustainable consumption behaviour across different consumer segments. Gonçalves et al. (2015) examine whether consump-


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tion values predict green buying behaviour. Choe and Kim (2018) studied the effects of tourists' local food consumption value on attitude, food destination image and behavioural intention. Zailani et al. (2019) applied the Theory of Consumption Values to Explain Drivers' Willingness to Pay for Biofuels.

Indeed, consumer choice is a function of multiple consumption values. Value is a personal and a subjective notion with intrinsic requirements and knowledge concerns and some implicit factors such as experiential needs (Biswas and Roy, 2015a, 2015b).

### 2.2. Impact of consumption values on consumer choice behaviour

The central consumption values are functional value, social value, environmental value, conditional value, knowledge value and epistemic value (Biswas and Roy, 2015a, 2015b; Lin and Huang, 2012; Lee et al.,2015; Rahnama and Rajabpour, 2017; Zailani et al., 2019).

#### 2.2.1. Functional value

Consumers' perception of product performance as durability, efficiency, reliability, price and quality is measured by functional value. It is considered the determinant factor of consumers' choice behaviour and decision to buy sustainable products (Sheth et al., 1991; Bei and Simpson, 1995; Biswas and Roy, 2015a, 2015b; Zailani & al., 2019; Rahnama and Rajabpour, 2017).

Bei and Simpson (1995) confirmed that consumers often find the products' price and quality as the most significant factors. Concerning sustainable products, practical interest is the first to control consumer choice behaviour. in the case of high-priced products, criteria other than the price would be selected by consumers (Zailani et al., 2019; Rahnama and Rajabpour, 2017).

Consumers' extreme sensitivity to the price of sustainable or pro-environmental products does not disclose much environmental responsibility (Malhotra et al., 2011, Zailani et al., 2019). In developed countries, the number of consumers willing to make radical reforms to fight against environmental degradation and willing to pay high prices for green products has improved (Wan and Birch, 2011; Lung, 2010; Zailani et al., 2019).

Many studies about olive oil consumers' preferences and perceptions highlight the importance of functional benefits like the taste, and the price, which are considered as means of research and experience quality attributes for olive oil choice and during the purchase decision. In addition, health, nutritional value and body weight have a significant impact on olive oil consumer choice, they represent experience and credence quality attributes (Mtimet et al., 2013, Siriex, 1999, 2007; Del Giudice et al., 2015; José Jiménez-Guerrero et al., 2012; Mtimet et al., 2013; Rodolfo and Mónica, 2016, Sandalidou and Siskos, 2002; Cândido et al., 2017, Salazar et al, 2017).

Based on this research, hypotheses1a, 1b, 1c and 1d can be developed.

**H1a.** Functional value-taste positively affects olive oil consumers' purchase decisions.
**H1b.** Functional value-price has a positive effect on olive oil consumers' purchase decisions.
**H1c.** Functional value-health positively affects olive oil consumers' purchase decisions.
**H1d.** Functional value-body weight negatively impacts olive oil consumers' purchase decisions.

#### 2.2.2. Emotional value

Emotional value refers to the product perceived value provoking feelings or affective states (interested, loving, pleasant, satisfied, secure) (Sheth et al., 1991; Rahnama and Rajabpour, 2017). Several studies (Desmet and Schifferstein, 2008; Gutjar et al., 2015; Johansen et al., 2011; King et al., 2010; O'Connor et al., 2005; Sosa et al., 2015; Rahnama and Rajabpour, 2017) proved the importance of emotion on foods choice and purchase. Consumers' behaviour regarding the environment is driven by emotional value (Lin and Huang, 2012; Sangroya and Nayak, 2017; Zailani & al., 2019; Rahnama and Rajabpour, 2017). So, hypothesis 2 is generated:

**H2.** Emotional value has a positive effect on olive oil consumers' purchase decisions.

#### 2.2.3. Economic, social, and environmental sustainability values

Consumer concerns about sustainability with its three dimensions (social, economic, and environmental dimensions) grow every day. While conscious of the relationship between environment and development, consumers change their consumption patterns and engage in pro-environmental behaviour (Wang & al, 2013; Kilbourne and Pickett, 2008; Biswas and Roy, 2015a, 2015b). Sustainable consumption refers to the consumer decision to buy (or not) a product based on social (promote employment and wellbeing), economic (long-term economic growth) and environmental (decreased natural resource use) criteria (Ramirez, 2013; Kataria, 2016; Biswas and Roy, 2015a, 2015b).

Many studies investigate sustainable consumption behaviour: pro-environmental behaviour, green consumption behaviour (Wang & al, 2013), household recycling, waste management behaviour (Barr et al, 2005), and domestic energy-saving behaviour (Gadenne et al., 2011; Biswas and Roy, 2015a, 2015b). Regarding olive oil consumption in Tunisia, as a green product, hence hypotheses3a and 3b can be generated: H3a. Economic and social sustainability values impact positively olive oil consumers' purchase decisions in the Tunisian market.

**H3b.** Environmental sustainability value affects positively olive oil consumers' purchase decisions in the Tunisian market.

### 2.2.4. Social value

The social value measured the perceived utility resulting from belonging to special social groups (socioeconomic, demographic, or cultural group). Social pressure greatly affects consumer choice (Sheth et al., 1991; Bei and Simpson, 1995; Biswas and Roy, 2015a, 2015b; Zailani et al., 2019). Pro-environmental behaviours are motivated by social engagement and responsibility. Many studies found a positive correlation between social value and sustainable consumption behaviours (Biswas and Roy, 2015a; Sweeney and Soutar, 2001; Zailani et al., 2019). Nevertheless, some studies postulate that consumer decision or choice is more affected by personal and subjective factors than social norms or pressure (Shamdasani et al., 1993; Biswas and Roy, 2015a, 2015b). Commonly, the consumers' purchase intentions are positively related to their perceptions of social value. Thus, hypothesis 4 is postulated:

**H4.** Social value has a positive effect on olive oil consumers' purchase decisions.

### 2.2.5. Conditional value

Conditional value refers to the utility obtained in a particular situation. Studies by Ottman (1998), Saxena and Khandelwal (2010), Niemeyer (2010) and Gadenne et al. (2011) assume that changes in consumer situational variables can affect consumers' choices (Biswas and Roy, 2015a, 2015b). A condition is a situation in which a consumer bases its decision on every element related to specific times and places, in addition to personal knowledge and stimulus attributes (Zailani et al., 2019). When personal situations get transformed, consumer purchase behaviour may change (Laaksonen, 1993; Zailani et al., 2019). Biswas and Roy (2015a), Rahnama & Rajabpour (2017) and Zailani et al. (2019) state that conditional value has a significant contribution to the adoption of sustainable consumption behaviour. Thus, hypothesis 5 is formulated:

**H5.** Conditional value has a positive effect on olive oil consumers' purchase decisions in the Tunisian market.

### 2.2.6. Knowledge and epistemic values

Awareness interest refers to the perceived utility generated to fulfil the lack of knowledge and pursue novelty. Consumer inclinations to satisfy a need for knowledge about product characteristics have a beneficial impact on consumer behaviour towards buying sustainable goods (Laroche et al., 2001; Tanner and Kast, 2003). Insufficient information about these products contributes to a discrepancy attitude between consumers' environmental concerns and their actual buying behaviour (Ginsberg and Bloom, 2004; Biswas and Roy, 2015a, 2015b). Zailani et al. (2019) assumes that a lack of information about products impacts consumers' behaviour and pushes them to adopt a sustainable consumption behaviour. Many studies have proven a positive correlation between consumers' knowledge and awareness, epistemic value, and sustainable consumption behaviours (Lin and Huang, 2012; Rahnama and Rajabpour, 2017; Suki,


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2016; Zailani et al., 2019). Therefore, hypothesis 6 was proposed:

**H6:** olive oil consumers' purchase decision is positively influenced by knowledge and epistemic values.

Figure 1 shows the proposed framework for the investigation of consumption values' impacts on Tunisian consumers olive oil choice.

## 3. Methodological approach

### 3.1. Database

This survey is based on data collected from a survey conducted on a sample of 250 households, of which 216 are usable questionnaires. Households are essentially localized in Tunis city centre and its suburbs, the north, and the centre of the country. They also originate in the different regions for better representativeness. Olive oil consumption differs by living environment. The questionnaire targets the household heads. The interviewees were 61% men, 68.5% married, 64% other than 31 years old and 44% with university educational level. 74% of the families are composed of more than four individuals (appendix 1). Income is an essential variable in determining olive oil consumption since it reflects the purchasing power of consumers. It is well distributed among the different income classes selected, with about 45% of the middle classes, whose income is between 1001 and 2000 TND (1EUR ≈3.2TND).

The questionnaire covers all the variables that can affect consumer behaviour. It is structured into four sections: consumption preferences and choice behaviour about edible oil, consumption values perception, purchases, and consumption (place of purchase, quantity, frequency, and budget) and finally, socio-demographic, and economic variables of the households.
Our assumptions focused on 34 items that we expect will influence consumer behaviour. These items belong to six dimensions of consumption values: functional, emotional, sustainability, social, conditional, and epistemic values. Each of the 34 items were measured with a score from 1 to 5, where 1 ="strongly disagree", 2 = "disagree", 3 = "indifferent", 4 = "agree ", 5 =" strongly agree ". So, the 34 selected items are introduced into the database in numerical forms.

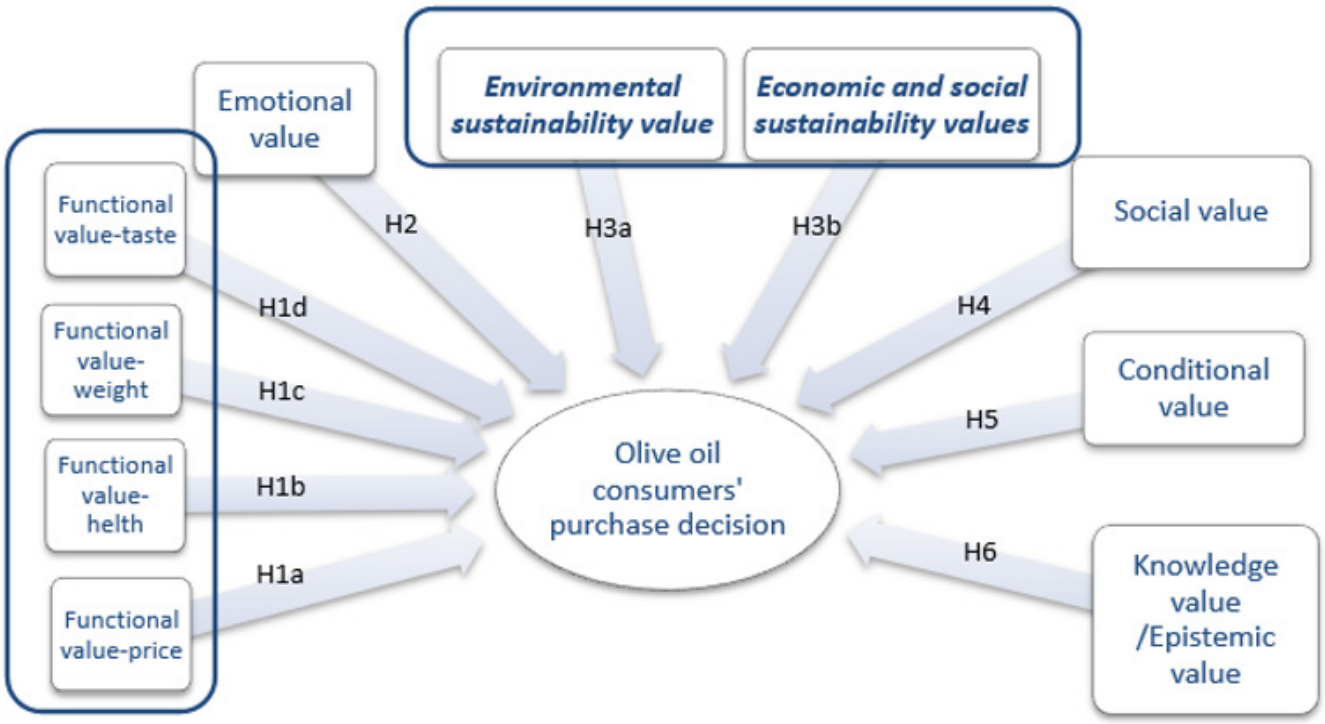


**Figure 1.** Research framework

### 3.2. Data statistical analysis

SPSS software (20.0) descriptive statistical analysis was used to determine the socio-demographic profile of the consumers and to describe respondents' behaviour towards olive oil (perception, purchase, and consumption).

An exploratory factor analysis was carried out to determine the principal dimensions among the variables. Out of the 34 items, 30 were factor-analysed, using principal component analysis (PCA) with the Varimax rotation method to establish the different dimensions of consumers' values. The varimax rotation is useful for maximizing the differences between the extracted components and to preserving the correlation within the components. The Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test were used to determine the suitability of the data. A KMO measurement of 0.6 or above indicates sufficient data for PCA (Ding and He, 2004). The items factor-analysed sets out details about the different dimensions of consumers' values.

Subsequently, a classification analysis (dynamic cloud classification) was executed using the consumption values dimensions as variables of the research. Group selection is based on the significance between variables and the type of group. This significance was detected according to the ANOVA variance analysis procedure and the chi-two ($\chi 2$) test. We then used a cross-tabulation procedure to determine consumer group profiles according to sociodemographic variables and consumption preferences. Knowing that the mathematical concept of logistic regression is to express the relationship between the outcome variable and predictor variables (independent variables) in terms of logit: the natural logarithm of odds, this method is helpful in this case study. It can be of different types, such as binomial (binary), multinomial, or ordinal, depending on the nature of the outcome variable. So, to evaluate the impact of consumers' value factors on olive oil purchase decisions, a binomial logistic regression is operated. The outcome variable has only two categories: it is a dichotomous outcome variable describing the purchase of olive oil ("1= olive oil purchase" and "0= non-purchase of olive oil"). The predictor variables refer to all the dimensions obtained from the previous factor.

## 4. Results and discussion

### 4.1. Tunisian consumers' behaviour toward olive oil

Our findings confirm that majority of olive oil purchased in Tunisia is in bulk. Indeed, more than 4/5 of our sample's (86.1%) purchase condition was in bulk. Opposite to the Italian and the US markets, the domestic consumption of Tunisian olive oil is based on family/friends' reserves and the direct supply of olive mills. More than half of the interviewees (53.7%) reported that they bought olive oil primarily from families and friends. 21.3% of interviewed consumers bought it directly from olive oil mills and producers. The market share of wholesalers, retail stores and weekly markets is less important, with respective percentages of 4.2 %, 4.6 % and 2.3% (appendix 2). The place of purchase is still related to consumers' culture and purchase habits. As detailed in appendix 3, Tunisian households consume on average 5,45 litres/month of olive oil with a standard deviation of 6,22; against an average of 6,59 litres/month of other edible oil (corn oil, sunflower seed oil, soybean oil, etc.) with a standard deviation of 3 litres/month.

By asking Tunisian consumers about their favourite edible oil, olive oil is ranked first for 82.4%of our household's sample. Corn oil, sunflower-seed oil, soybean oil, and other edible oils are preferred by 17.6% of our sample. Despite these preferences, Tunisians consume in more significant quantities the other edible oils sold at lower prices and even at State-subsidized prices because of budgetary constraints.
About the consumption mode, the olive oil is mainly used for breakfast for 83.3% of Tunisian consumers and for salad dressing (75.5 %); it is used as edible oil to add directly to the dishes for 67.1%. About half of our sample consider olive oil convenient for cooking. According to Tunisian dietary habits, olive oil is not appropriate for frying; only 2% use it for this purpose (appendix 4).

### 4.2. Factor analysis results of the olive oil consumption values

Respondents were asked to express, with a score from 1 to 5, what consumption values they consider when buying olive oil (appendix 5). Among the 34 items, the most important are "Health and nutritional prod-


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ucts"(average score of 4.91), "Good taste products" (4.81)," Olive oil consumption is interesting" (4.68), " High Price Product"(4.61) and " It's pleasant to consume olive oil"(4.6). The less important values are "Increases body weight"(2.67), "I buy if the product is advertised" (2.41), "Easily substitutable product" (2.03), and "a cheap product" (1.44).

Using Principal Component Analysis (PCA) and the Varimax rotation method, we factor-analysed thirty items and established different dimensions of quality (appendix 6). Value of 0.731 for the Kaiser–Meyer–Olkin (KMO) measure indicates that data are adequate for PCA, and Bartlett's test was significant.

Exploratory factor analysis with Varimax rotation of the 30 variables resulted in a nine constructs solution that explains 69% of the total variance. All nine factors had Eigenvalues greater than 1 (appendix 6).

The first construct of consumption values was labelled as "Environmental sustainability value", which explained 15.85 % of the total variance. It is determined by items related to sustainable agricultural production systems with sustainable food labels and certificates, systems with less loss of waste, and systems based on fair trade since it is deeply connected to environmental protection in addition to social impact.

The second construct, "conditional value", includes five items and explains 11.01% of the total variance. In fact, consumers' olive oil preferences are subject to some conditions like promotion, advertisement, product availability on the market, State subsidies, and products' traceability.

The third construct, "Emotional value", focuses on four items: "pleasant to consume, makes the consumer relax, makes the consumer feel good". It explains 7.34% of the total variance.

The fourth construct, "Functional Value-Price», explaining 6.84% of the total variance, is determined by two items (Cheap Product/High Price Product).

The fifth construct called "Functional Value-Weight "combines the attributes related to the influence of olive oil consumption on weight. This dimension explains 6.49% of the total variance.

The sixth construct called "Economic and social sustainability values", which explained 6.25% of the total variance, covers two items "olive oil purchase help to promote employment in Tunisia" and "it contributes to the economic development of the country".

The seventh construct relative to "Social value" explains 5.8% of the total variance; it is based on the socio-cultural context of olive oil consumption in Tunisia: consumption habits and situations and modes of use.

The eighth construct, explaining 4.81% of the total variance, was labelled " Functional value- Health". It includes items related to the Tunisian perception of the impact of olive oil consumption on human health (Omega-3 and omega-6 antioxidants contents, nutritional value).

The "Epistemic value" represents the ninth construct of the Tunisian consumption values, with 4.57% of the total variance. It refers to three items about consumer information and innovation needs.

Figure 2 illustrates the components of the two main factors, environmental sustainability value, and conditional value, via a two-dimensional plot.

Knowing that the most common and reliable criterion in extracting factors is the use of Eigenvalues, all factors are with Eigenvalues greater than 1, so they were retained because they were considered significant. These nine dimensions of olive oil consumption values are used for cluster analysis (1) and as predictor variables to identify factors determining Tunisian consumers' preference for olive oil (2).

### 4.3. Cluster analysis of Tunisian olive oil consumers

Classification analysis was performed using nine factors of olive oil consumption to identify consumer segments. The option for three groups was selected based on the profile of the selected groups and the significance of the analytical variables. The ANOVA analysis shows the significance of five factors at $p < 0.001$ (Environmental sustainability value, Emotional value, Functional Value-Price, Economic and social sustainability values, and Conditional Value).
Regarding the consumption values, the average score

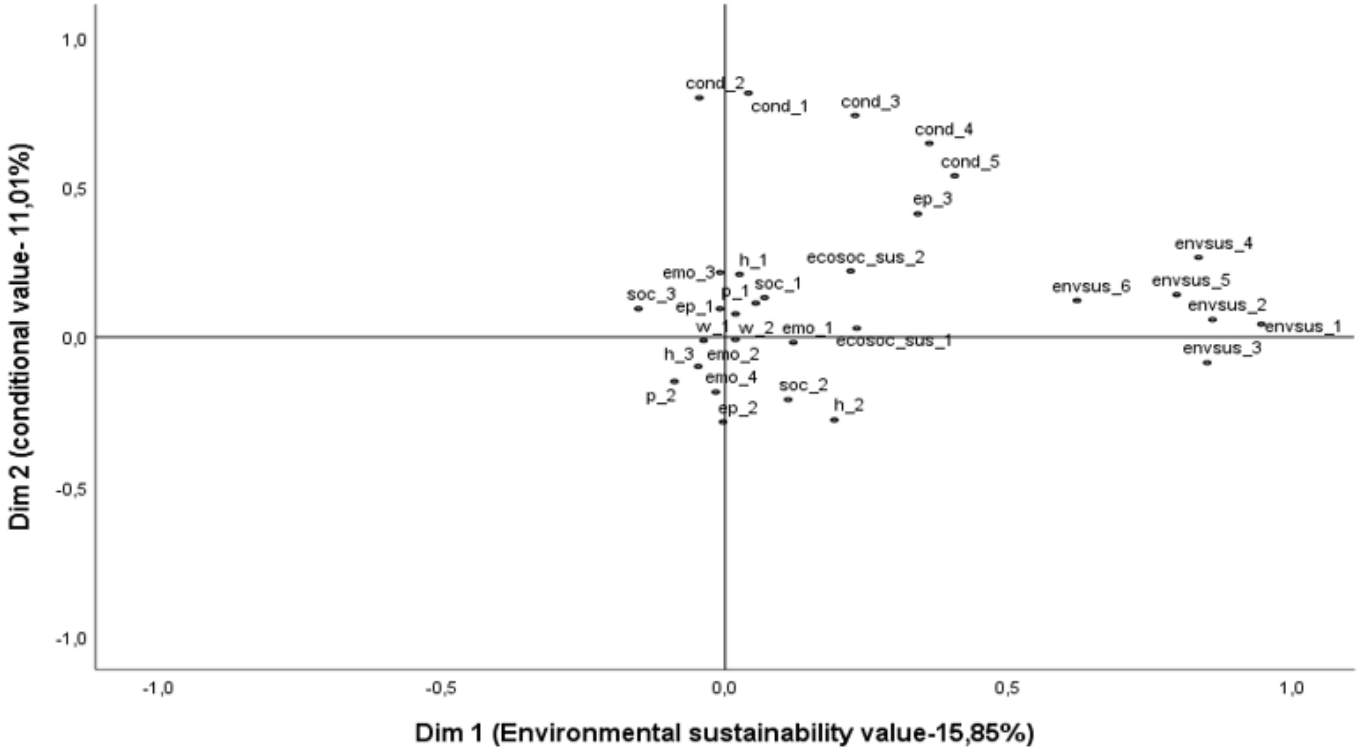


**Figure2.** The components of the two principal factors Environmental sustainability value and conditional value (2D plot)
(Abbreviations detailed in appendix 6)

of the selected groups varies between -0.33 and 0.1 (Table 1). This outcome confirms the difference between the three groups concerning their sensibility to the nine dimensions of consumption values. Price is the most critical factor in the cluster analysis (F=369). The first group represents "price-sensitive consumers", with a negative score for the price, as a functional value (score of -2,747). It includes 20 consumers representing 9.26% of the sample. The second group, "Consumers with environmental sustainability concerns", attributes modest scores to the different factors (scores between -1 and 0.5). This group gives special attention to environmental sustainability and represents the less emotional consumers. This group consists of 52 consumers (24.07% of the sample). Group 3, "Emotional consumers with economic and social sustainability concerns", is more concerned with the "Emotional value " with a score of 0.395 and "Economic and social sustainability value" with a score of 0.175. It has 144 consumers representing 66.67% of the sample.

Figure 3 illustrates the dispersion of Tunisian olive oil consumers according to the three main classification factors: the price as a functional value, the emotional value, and the environmental sustainability value.

The analysis carried out highlights the segmentation of the olive oil market in Tunisia. The three consumer groups have different socio-demographic and economic profiles (Appendix 7). Statically significant variables are related to origin, location, and household size.

About 66% of "Price sensitive consumers" are from and live in Sidi Bouzid, which is the second olive production area in Tunisia (FAO, 2015). The vocation of the region of origin acts on consumers' values, habits, and decisions. This group is composed of the highest average household size (5). The whole group buy olive oil with different purchase frequencies. 40% of this group purchase olive oil 1-2/month, especially from family/friends (95%). They have the highest consumption (11 litres/month). Their consumption of large quantities of olive oil and their relatively large household size increases their price sensitivity. They


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**Table 1.** Cluster analysis based on the nine constructs of olive oil consumption values

| | | | Consumer clusters | | |
|---|---|---|---|---|---|
| | | | **1** | **2** | **3** |
| Number of observations per class | | | 20 | 52 | 144 |
| % Per class | | | **9,26** | **24,07** | **66,67** |
| Profit | | | **1** | **2** | **3** |
| **Factors** | **F** | **Sig** | **Price sensitive consumers** | **Consumers with environmental sustainability concerns** | **Emotional consumers with economic and social sustainability concerns** |
| Environmental sustainability value | **10,644** | * | -0,224 | **0,533** | -0,161 |
| Conditional Value | **6,471** | * | -0,326 | -0,342 | 0,169 |
| Emotional value | **69,009** | * | -0,004 | -1,093 | **0,395** |
| Functional value-Price | **369,654** | * | **-2,747** | 0,373 | 0,247 |
| Functional value-Weight | 0,185 | | 0,056 | -0,071 | 0,018 |
| Economic and social sustainability values | **8,691** | * | -0,024 | -0,476 | **0,175** |
| Social value | 1,783 | | 0,264 | 0,141 | -0,088 |
| Functional value- Health | 0,362 | | -0,014 | -0,100 | 0,038 |
| Epistemic value | 1,588 | | 0,057 | -0,215 | 0,070 |
| **Means** | 52,043 | | -0,329 | -0,139 | 0,096 |

*Statistically significant for p < 1%

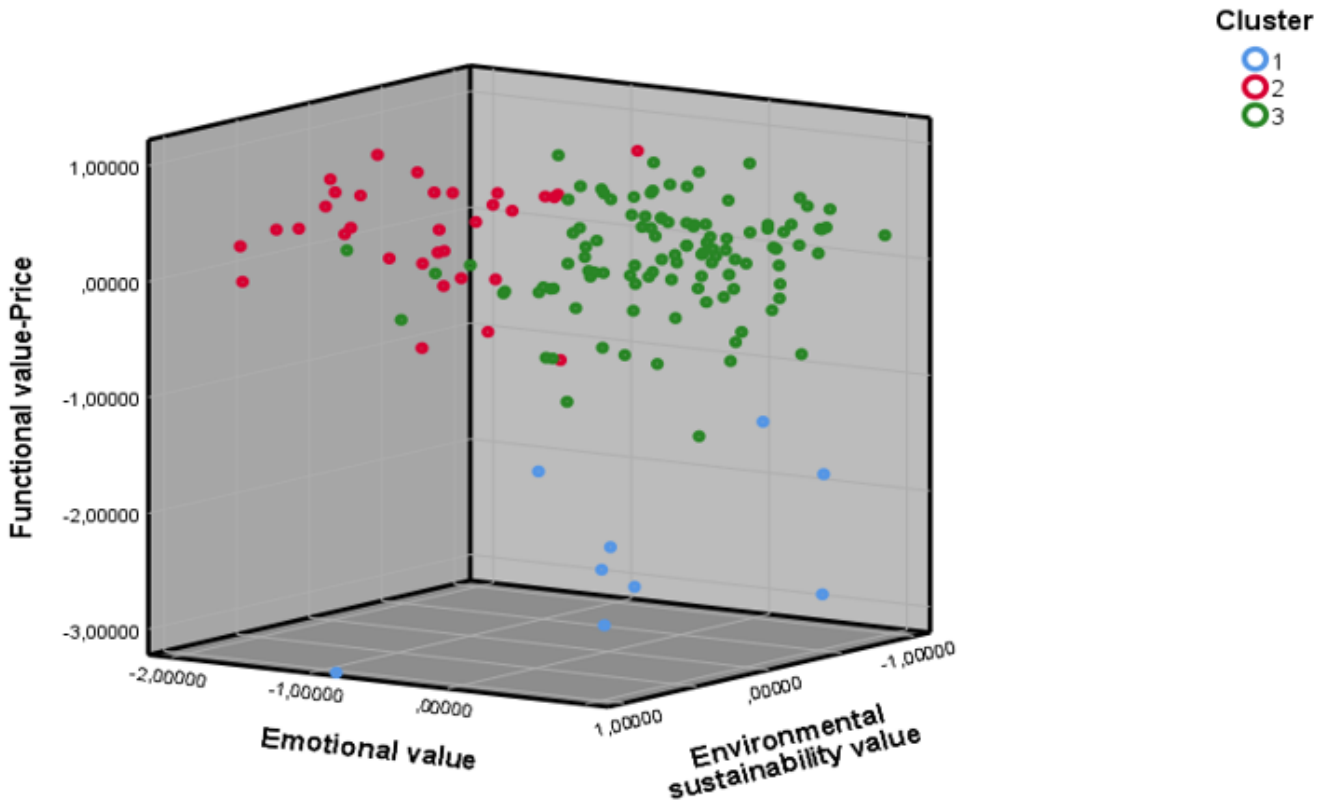


**Figure3.** Olive oil consumers dispersion according to the three main classification factors (3D plot)

are also concerned with social values since the product is part of their social heritage and their diet.

Almost half of the second group, qualified by "Consumers with environmental sustainability concerns", is also from and lives in Sidi Bouzid, with a household average size of 4 members. It represents 24% of the sample. This class of consumers has a different consumption and purchase behaviour: 23% of consumers belonging to this class buy olive oil only once per year, especially from family and friends for 60% of cases and from mils for 13.5%. They have an average monthly consumption of olive oil of about 7 litres. Compared with the first group, they consume less olive oil and buy it less frequently. They are less sensitive to price, and economic and social values and more concerned with environmental values.

The third consumers category, "Emotional consumers with economic and social sustainability concerns", is equivalent to 67% of the sample. These consumers are mainly from Kef and live there. Kef Governorate is ranked 14th in terms of olive growing area. These consumers also have an average household size of 4 members. About 49% of them buy olive oil monthly (1-2/month), from relatives (46%) and mills (26%). They have the lowest average olive oil consumption (4 litres/month). They are more sensitive to emotional values (pleasure, relaxation) than the two other groups and give significant weight to economic and social sustainability values during the purchase decision.

### 4.4. Consumer values determining olive oil purchase

All nine dimensions of the olive oil consumption values were taken into consideration in the Binary logistic regression analysis, and the dependent variable (categorical variable) was considered "the purchase of olive oil" with two values, 1 or 0:

**1:** olive oil purchase,
**0:** non-purchase of olive oil.

The logistic regression can use two indicators such as Cox and Snell R2 and Nagelkerke R2 to estimate the contribution of the predictor variables to the variability of the dependent variable. Nagelkerke R2 indicator evaluates the contribution of all predictor variables to the variability of the dependent variable. Knowing that Cox and Snell R2 indicator usually underestimates the real value, the test results (Table 2) based on the nine predictor variables could explain 51% of the effect of the environment on the artefacts.

The results from the classification table (Table 3) showed that the mathematical model predicts 90.7% of cases correctly. Thus, it is considered as a performing model. Its regression coefficients (β) are shown in "Variables in the equation" (Table 4).

Nine predictive variables were investigated by regression analysis. Only six of them had a statistical significance: "Environmental sustainability value, Conditional Value, Emotional value, Functional Value-Price, Social value and Epistemic value".

"Functional Value-Weight", "Economic and social sustainability values", and "Functional value- Health" have no statistically significant effect on the olive oil purchase decisions. Therefore, the assumptions H1c, H1b and H3b are invalid.
Environmental sustainability value has a positive and statistically significant impact on the purchase decision. The probability of buying olive oil increases as consumers' sensitivity to "Environmental sustainability value" increases (Odds ratio=3.13). In addition, consumers who attach greater importance to emotional value have a higher probability of purchasing olive oil (Odds ratio=1.66). Moreover, consumers who attach greater importance to social value have a relative likelihood of olive oil purchase 3.35 times more substantial. It is the same with "Epistemic value" that has a positive and statically significant impact on olive oil purchase decisions in the Tunisian market. Thus, the assumptions H2, H3a, H4 and H6 are empirically valid.

The more importance Tunisian consumers attach to conditional value and olive oil price (as functional value), the lower the probability of buying olive oil (Odds ratio conditional value=0.192, odds ratio price=0.418). Thus, hypotheses H1a and H5 are to be qualified since these two consumers' values have a negative and statically significant impact on the olive oil purchasing decisions. Indeed, the more sensitive the consumer is to the price, the more he connects the


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purchase of olive oil to promotions and subsidies.

Since many studies have used quality attributes to investigate the purchasing and consumption of olive oil behaviour (Nicole et al., 2010; Karipidis et al., 2005), Santosa and Guinard (2011), through a means-end chains analysis, tried to explore olive oil consumption and buying motivations in the Californian market. It highlights the attributes and values that are relevant to this consumer behaviour. It reveals the importance of environmental caring and sustainability, financial responsibility (functional value /price), functional value/health, supporting the local economy (social and economic sustainability value) et especially pleasure (emotional value). Accordingly, environmental sustainability, price as a functional value and emotional value are mean values determining olive oil purchase in both Tunisian and Californian markets. Unlike the Californian consumers, epistemic and social values affect Tunisian consumers' purchase decision of olive oil. Besides, Californian consumers based their olive oil purchase decision on health as functional value and social and economic sustainability value.

## 5. Conclusion

In this study, we explored the impact of consumer values and especially the value of environmental sustainability in order to examine the behaviour of Tunisians regarding olive oil. A descriptive analysis of Tunisian consumers' behaviour toward olive oil was proposed. The results of our research prove that the purchases of olive oil on the Tunisian market are made essentially in bulk contrary to the Italian and the US markets. The place of purchase is still related to consumers' culture and purchase habits. Tunisian households consume, on average, 5,45 litres/month of olive oil, against an average of 6,59 litres/month of other edible oil (corn oil, sunflower-seed oil, soybean oil, etc.). But olive oil remains the most preferred. Olive oil is mainly used for breakfast and salad dressing. Half of our sample considers olive oil convenient for cooking and not for frying.

For Tunisian consumers, the essential values considered for purchase decisions are health and nutritional value, taste, price as functional values, and interesting and pleasant consumption as emotional values. In

**Table 2.** Binary logistic regression of the model— (Backward stepwise LR)

| Model summary | | | |
|---|---|---|---|
| Step | −2 log-likelihood | Cox and Snell $R^2$ | Nagelkerke $R^2$ |
| 4 | 102,399 [a] | ,282 | ,510 |

[a] Estimation terminated at iteration number 7 because parameter estimates changed by less than 0.001.

**Table 3.** Binary logistic regression of the model (Backward stepwise LR)- Classification table [a]

| | | Predicted | | |
|---|---|---|---|---|
| | | Olive oil preference | | |
| | | 0.00 | 1.00 | Percentage correct |
| Observed | Olive oil preference | | | |
| Step 7 | 0.00 | 17 | 13 | 56,7 |
| | 1.00 | 7 | 179 | 96,2 |
| | Overall percentage | | | 90,7 |

[a] The cut value is 0.500.

**Table 4. Results of binary regression model—Backward stepwise LR**

| Parameters | | β | S. E.β | Wald $\chi_2$ | Degrees of freedom | P-value | Exp (β) |
|---|---|---|---|---|---|---|---|
| Step4 [a] | **Environmental sustainability value** | 1,141 | ,430 | 7,040 | 1 | ,008 [b] | 3,130 |
| | Conditional Value | -1,651 | ,455 | 13,151 | 1 | ,000 [b] | ,192 |
| | **Emotional value** | ,510 | ,206 | 6,133 | 1 | ,013 [c] | 1,665 |
| | Functional value-Price | -,873 | ,479 | 3,314 | 1 | ,069 [d] | ,418 |
| | **Social value** | 1,210 | ,257 | 22,103 | 1 | ,000 [b] | 3,353 |
| | Epistemic value | ,805 | ,325 | 6,127 | 1 | ,013 [c] | 2,237 |
| | Constant | 3,477 | ,540 | 41,483 | 1 | ,000 [b] | 32,347 |

a. Nine variables entered in step 1
b. Statistically significant for p < 1%
c. Statistically significant for p < 5%

contrast, the less important values are impact on body weight as functional value, conditional values such as advertisement dependency, in addition to product substitutability.

The exploratory factor analysis reveals nine dimensions among consumers' values. The first construct of consumption values is "Environmental sustainability value", and it explains 15.85 % of the total variance; it is determined by items related to sustainable agricultural production systems. The second construct, "conditional value", explains 11.01% of the total variance. "Emotional value, Functional value-Price, Functional value-weight, Economic and social sustainability values, Social value, Functional value-Health, and Epistemic Value" are dimensions that also derive from our analysis.

Based on these nine constructs of consumers values, a cluster analysis was performed and revealed three consumers groups: "price-sensitive consumers" (9.26% of the sample), "Consumers with environmental sustainability concerns" (24.07%), and "Emotional consumers with economic and social sustainability concerns" (66.67%).

To evaluate the impact of consumers' values on olive oil purchase decisions, a binomial logistic regression is proposed. Results release that "Functional value-Weight, Economic and social sustainability values and Functional value- Health" have no statistically significant effect on the olive oil purchase decisions. However, "Environmental sustainability value, Emotional value, Social value, and Epistemic value" had a positive and statistically significant impact on olive oil purchase, unlike conditional value and functional value/Price, which had a negative and statically significant impact on olive oil purchase.

These findings are beneficial for Tunisian olive oil suppliers and policymakers to adopt marketing strategies based on client preferences. The originality of the paper consists in revealing the values on which consumers base their choice and purchase of olive oil. At the same time, almost all studies have used only quality attributes and indicators for this purpose.

According to these results, promoting olive oil on the Tunisian market may be based on "Environmental sustainability value, Emotional value, Social value, and Epistemic value". Firms must communicate about the contribution of the olive oil sector to environmental sustainability through organic production systems and protected designations of origin. Marketing olive oil may also be based on emotional (pleasure, feelings, relaxation, etc.) and social consumer values (Tunisian diet, family events, substitutability, etc.). Managers must communicate about olive oil origin, crushing techniques, varieties, and taste. They must offer more innovation to Tunisian consumers like aromatized and vaporizing oils. In addition, firms' mix marketing, especially regarding price and advertising, must


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consider the sensitivity of consumers to prices and to promotion. These recommendations emerge from our exploratory analysis of a small sample of Tunisian olive oil consumers. The descriptive approach represents the main limitation of this work. Further investigation of olive oil consumer behaviour based on consumption values should be conducted for a better extrapolation of the results.

**Conflict of interest:** The authors declare no conflict of interest.

**Appendix 1. Socio-demographic profile of the sample (N=216)**

| **Gender** | | | | | | |
|---|---|---|---|---|---|---|
| Male | Female | | | | | |
| **61,1** | 38,9 | | | | | |
| **Age** | | | | | | |
| ≤30 | 31-40 | 41-50 | > 50 | | | |
| 9,3 | **30,6** | **33,3** | **26,9** | | | |
| **Origin** | | | | | | |
| Tunis city | | North | Centre | South | | |
| 18 | | 41,3 | 37,1 | 3,7 | | |
| **Marital status** | | | | | | |
| Married | Other | | | | | |
| **68,5** | 31,5 | | | | | |
| **Place of residence** | | | | | | |
| North | Tunis city | | Centre | South | | |
| 32,9 | 33,3 | | 33,3 | 0,5 | | |
| **Educational level** | | | | | | |
| Analphabet | Koranic school | Primary | Secondary | University | | |
| 1,9 | 2,3 | 20,4 | 31,5 | **44** | | |
| **Household monthly income** | | | | | | |
| ≤500 TD | 501-1000 | 1001-1500 | 1501-2000 | 2001-2500 | 2501-3000 | >3000 |
| 5,6 | 27,3 | **25,9** | **18,5** | 9,3 | 6,5 | 6,9 |
| **Household's size** | | | | | | |
| 1 | 2 | 3 | 4 | 5 | >6 | |
| 3,7 | 9,7 | 13 | **26,8** | **26,8** | **20** | |

**Appendix 2. Purchasing place choice for olive oil**

| **Purchasing place of olive oil (%)** | | | | | |
|---|---|---|---|---|---|
| No purchase | Retail stores | Olive oil producers/mills | Weekly market | Wholesalers | Friends and relatives |
| 13,9 | 4,6 | **21,3** | 2,3 | 4,2 | **53,7** |

**Appendix 3. Edible oil monthly consumption per Tunisian household (litres/month)**

| | **Minimum** | **Maximum** | **Mean** | **Standard deviation (SD)** |
|---|---|---|---|---|
| **Olive oil** | 0 | 25 | 6,59 | 3,07 |
| **Other edible oil** | 0 | 42 | 5,45 | 6,22 |

## Appendix 4. Consumption mode of olive oil

| Consumption mode of olive oil (%) | | | | | |
|---|---|---|---|---|---|
| For salad dressing | Edible oil to add to the dishes | Frying oil | Cooking oil | Oil for pastries | Oil for breakfast |
| **75,5** | **67,1** | 1,9 | 51,4 | 38,4 | **83,3** |

## Appendix 5. Tunisian consumers' perception of proposed items of consumption values

| Items of consumption values | Mean | Standard deviation (SD) |
|---|---|---|
| Health and nutritional products | 4,91 | 0,438 |
| Good taste products | 4,85 | 0,431 |
| Olive oil consumption is interesting | 4,68 | 0,763 |
| High Price Product | 4,65 | 0,886 |
| It's pleasant to consume olive oil | 4,6 | 0,721 |
| Part of our consumption Habits | 4,37 | 1,048 |
| Product with antioxidants | 4,36 | 0,77 |
| Product intended for export | 4,3 | 0,939 |
| Omega-3 and omega-6 rich product | 4,19 | 0,751 |
| Using olive oil, I have self-esteem | 4,19 | 1,12 |
| I buy if the product is organic | 4,06 | 1,187 |
| Consuming olive oil makes me feel good | 3,98 | 1,27 |
| Low in cholesterol and trans fatty acids | 3,93 | 1,778 |
| Consuming olive oil makes me relax | 3,91 | 1,278 |
| I buy if it is from sustainable agricultural production | 3,85 | 1,115 |
| I buy if the product is not being lost and wasted | 3,81 | 1,046 |
| I buy if it is with controlled label of origin | 3,77 | 1,194 |
| I buy if there are State subsidies | 3,73 | 1,266 |
| I buy if the product respects the environment | 3,72 | 1,099 |
| I buy if it respects fair trade | 3,72 | 1,212 |
| Product widely consumed in family events (weddings, parties, guests, etc.) | 3,59 | 1,28 |
| Before buying, I need some information | 3,5 | 1,5 |
| Through olive oil purchase, I am helping to promote employment in Tunisia | 3,36 | 1,061 |
| Body Weight Control | 3,31 | 1,299 |
| I buy olive oil if it contributes to the economic development of the country | 3,23 | 1,071 |
| I buy if available | 3,18 | 1,235 |
| I want new information about the product | 3,09 | 1,232 |
| I am looking for new and different products | 3 | 1,263 |
| I buy if there are promotions | 2,94 | 1,428 |
| Before buying, I want a lot of information | 2,93 | 1,386 |
| Increases body weight | 2,67 | 1,272 |
| I buy if the product is advertised | 2,41 | 1,061 |
| Easily substitutable product | 2,03 | 1,27 |
| A cheap product | 1,44 | 0,933 |

**Appendix 6.** Factor analysis results of consumption values' items - Varimax rotation


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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kaiser–Meyer–Olkin (KMO) Measure of sampling adequacy** | | | 0.731 | | | | | | | | |
| **Bartlett's test for sphericity** | **Approx. chi-square** | | 3230,71 | | | | | | | | |
| | **df** | | 435 | | | | | | | | |
| | **Sig** | | 0,000 | | | | | | | | |
| | **Code** | **FACTORS** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| **Factor 1 Environmental sustainability value** | envsus_1 | I buy if it is from sustainable agricultural | 0,946 | 0,043 | -0,022 | -0,011 | -0,031 | 0,048 | 0,098 | 0,006 | -0,024 |
| | envsus_2 | I buy if the product is not being lost and wasted | 0,86 | 0,058 | 0,057 | 0,033 | -0,087 | 0,032 | 0,055 | 0,048 | -0,081 |
| | envsus_3 | I buy if it respects fair trade | 0,851 | -0,086 | -0,134 | -0,066 | -0,011 | 0,094 | 0,109 | 0,034 | 0,049 |
| | envsus_4 | I buy if the product is organic | 0,835 | 0,265 | 0,068 | 0,069 | -0,002 | 0,097 | -0,047 | 0,071 | 0,052 |
| | envsus_5 | I buy if the product respects the environment | 0,797 | 0,141 | -0,003 | 0,017 | 0,057 | 0,11 | 0,127 | 0,04 | 0,069 |
| | envsus_6 | I buy if it is with controlled label of origin | 0,621 | 0,122 | 0,128 | 0,202 | 0,124 | 0,21 | -0,007 | 0,025 | 0,053 |
| **Factor 2 Conditional Value** | cond_1 | I buy if there are promotions | 0,041 | 0,815 | 0,05 | 0,161 | -0,12 | 0,115 | -0,093 | -0,033 | 0,108 |
| | cond_2 | I buy if the product is advertised | -0,046 | 0,799 | -0,018 | -0,032 | 0,026 | -0,104 | 0,034 | 0,071 | -0,054 |
| | cond_3 | I buy if available | 0,229 | 0,74 | -0,066 | 0,163 | -0,049 | 0,167 | -0,044 | -0,043 | -0,141 |
| | cond_4 | I buy if there are State subsidies | 0,36 | 0,647 | 0,008 | 0,19 | 0,11 | 0,136 | -0,01 | -0,1 | -0,06 |
| | cond_5 | I buy if there is a product's traceability | 0,405 | 0,538 | 0,161 | -0,199 | -0,059 | 0,086 | -0,13 | 0,021 | 0,439 |
| **Factor 3 Emotional value** | emo_1 | It's pleasant to consume olive oil | 0,12 | -0,018 | 0,748 | 0,03 | 0,103 | -0,023 | 0,094 | 0,147 | 0,001 |
| | emo_2 | Olive oil consumption is interesting | -0,038 | -0,012 | 0,713 | -0,072 | 0,011 | -0,037 | 0,038 | 0,05 | 0,067 |
| | emo_3 | Consuming olive oil makes me relax | -0,009 | 0,215 | 0,7 | 0,063 | 0,019 | -0,106 | -0,14 | 0,054 | -0,074 |
| | emo_4 | Consuming olive oil makes me feel good | -0,017 | -0,184 | 0,514 | 0,04 | 0,06 | 0,276 | 0,242 | -0,209 | -0,02 |
| **Factor 4 Functional value-Price** | p_1 | High Price Product | 0,054 | 0,113 | 0,019 | 0,937 | 0,015 | 0,045 | -0,059 | -0,032 | -0,016 |
| | p_2 | A cheap Product | -0,089 | -0,149 | -0,024 | -0,92 | 0,029 | 0,008 | 0,1 | -0,027 | 0,041 |
| **Factor 5 Functional value-Weight** | w_1 | Bodyweight Control | 0,018 | -0,009 | 0,078 | -0,046 | 0,946 | 0,004 | 0,046 | 0,058 | -0,039 |
| | w_2 | Increases bodyweight | 0,018 | 0,077 | -0,086 | -0,052 | -0,934 | -0,046 | 0,024 | -0,032 | -0,062 |
| **Factor 6 Economical and social sustainability** | ecosoc_sus_1 | Through olive oil purchase, I am helping to promote employment in Tunisia | 0,232 | 0,029 | -0,005 | 0,007 | 0,003 | 0,805 | 0,069 | 0,04 | -0,021 |
| | ecosoc_sus_2 | I buy olive oil if it contributes to the economic development of the country | 0,221 | 0,22 | -0,069 | 0,039 | 0,057 | 0,781 | -0,002 | 0,119 | -0,039 |
| **Factor 7 Social value** | soc_1 | Product widely consumed in family events | 0,07 | 0,131 | -0,051 | -0,1 | 0,004 | 0,051 | 0,842 | 0,077 | 0,03 |
| | soc_2 | Part of our consumption Habits | 0,111 | -0,209 | 0,064 | -0,093 | -0,021 | 0,109 | 0,738 | 0,096 | 0,051 |
| | soc_3 | Easily substitutable product | -0,153 | 0,094 | -0,32 | -0,07 | -0,063 | 0,269 | -0,503 | 0,141 | -0,077 |
| **Factor 8 Functional value- Health** | h_1 | Omega-3 and omega-6 rich product | 0,025 | 0,209 | 0,131 | 0,04 | 0,028 | 0,098 | 0,079 | 0,824 | -0,092 |
| | h_2 | Product with antioxidants | 0,193 | -0,277 | -0,015 | -0,108 | 0,128 | 0,053 | 0,02 | 0,698 | 0,114 |
| | h_3 | Health and nutritional products | -0,047 | -0,099 | 0,291 | 0,188 | -0,263 | 0,017 | 0,03 | 0,34 | 0,193 |
| **Factor 9 Epistemic value** | ep_1 | I am looking for new and different products | -0,009 | 0,094 | 0,128 | -0,088 | 0 | -0,371 | 0,051 | 0,044 | 0,699 |
| | ep_2 | Information on olive oil markets, particularly for | -0,004 | -0,284 | -0,189 | 0,093 | 0,048 | 0,149 | 0,166 | -0,007 | 0,593 |
| | ep_3 | Before buying, I want a lot of information | 0,34 | 0,411 | 0,141 | -0,199 | -0,091 | 0,33 | -0,121 | 0,069 | 0,441 |
| **FACTOR STATISTICS** | **Eigen values** | | 4,755 | 3,303 | 2,201 | 2,051 | 1,946 | 1,876 | 1,74 | 1,445 | 1,373 |
| | **% of variance** | | **15,849** | 11,01 | 7,338 | 6,837 | 6,488 | 6,253 | 5,8 | 4,818 | 4,576 |
| | **Cumulative variance** | | 15,849 | 26,859 | 34,197 | 41,034 | 47,523 | 53,775 | 59,575 | 64,393 | **68,968** |

**Appendix 7. Description of the three clusters of olive oil consumers**

| | Groups | Price sensitive consumers | Consumers with environmental sustainability concerns | Emotional consumers with economic and social sustainability concerns | $\chi_2$ tests |
|---|---|---|---|---|---|
| **Gender (%per group)** | Male | 60,00 | 63,46 | 60,42 | ,923 |
| **Age (%per group)** | ≤ 40 | 40,00 | 40,38 | 39,58 | ,528 |
| | 41-50 | 20,00 | 38,46 | 33,33 | |
| | >50 | 40,00 | 21,15 | 27,08 | |
| **Origin (%per group)** | Tunis | 15,00 | 15,38 | 18,06 | ,000 |
| | Kef | 10,00 | 17,31 | **42,36** | |
| | Sidi Bouzid | **60,00** | **51,92** | 24,31 | |
| | Other | 15,00 | 15,38 | 15,28 | |
| **Location (%per group)** | Kef | 15,00 | 11,54 | **43,06** | ,000 |
| | Tunis | 10,00 | 13,46 | 16,67 | |
| | Sidi Bouzid | **60,00** | **48,08** | 24,31 | |
| | Other | 15,00 | 26,92 | 15,97 | |
| **Education (%per group)** | Higher education | 45,00 | 48,08 | 42,36 | ,746 |
| **Household income (%per group)** | ≤ 1500 | 35,00 | **61,54** | **61,11** | ,306 |
| | >1501 | **65,00** | 38,46 | 38,89 | |
| **Household size (mean)** | Household size | 5,20 | 4,23 | 4,22 | ,023 |
| **Olive oil purchase (%per group)** | Olive oil purchase | **100,00** | 84,62 | 84,72 | ,169 |
| **Purchase frequency (%per group)** | 1/year | 0,00 | **23,08** | 13,89 | ,001 |
| | 1-2/month | **40,00** | 9,62 | **48,61** | |
| **Place of purchase (%per group)** | Mills | 5,00 | 13,46 | 26,39 | ,015 |
| | Family/friends | **95,00** | **59,62** | **45,83** | |
| **Olive oil consumed per month (mean in litres/month)** | | **11,09** | 6,82 | 4,17 | ,000 |
| **Preference** | Olive oil is the most preferred oil | 85,00 | 86,54 | 80,56 | ,593 |

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# Valuing environmentally sustainable agriculture? Food and water concerns, production literacy, and consumption behaviours in rural-regional Australia

**ANGELA T. RAGUSA[1*], ANDREA CRAMPTON[2]**

[1] School of Social Work & Arts, Charles Sturt University, Albury NSW, Australia
[2]School of Dentistry & Medical Sciences, Charles Sturt University, Albury NSW, Australia

* Corresponding author: aragusa@csu.edu.au

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Although Australia currently enjoys a high level of food security, increasing climate change pressure on the planet's driest landmass which is governed by little climate change mitigating legislation, makes future food security tenuous in globalised, industrial food production systems. This article presents primary data exploring the salience of food and water concerns, compared with related knowledge, affecting agricultural product consumption. Online survey respondents (employees at a large organisation that states its values creating environmentally sustainable rural-regional communities while educating health, science, and agricultural professionals) demonstrated low pro-environmental sustainability literacy and behaviour regarding food and water consumption choices, despite having sustainability concerns and high level of education, including formal environmental science training. Data are contextualised amid interdisciplinary research and theory to further sociologically understand knowledge gaps about food choices and (un)awareness of conventional agricultural food/water production implications affecting socioeconomic and environmental sustainability. Given expansive literature argues sustainability initiatives must derive from individual and private sector action-taking, rather than await governmental change, the article argues policy and practice changes must prioritise knowledge-action gaps and value divergences. Research interrogating why low literacy about sustainable production and consumption practices persist is advocated to enhance consumer awareness and behaviour following internationally recommended pro-environment action-taking necessary for sustained global food/water security that facilitates agricultural sector capacity to support human and environmental health.

## 1. Introduction

Australia's natural environment bifurcates between extreme drought and flooding, experiences excessive heat, and has a small portion of arable land relative to its size. Although agribusiness technologies strive to increase productivity in challenging climate conditions, socio-cultural values inform food and water practices that perpetuate soil erosion and food insecurity fears as economic profit and short-term goals receive priority compared with historical 'pastoral care' approaches to natural resource management (Kopittke *et al.,* 2019). Australia ranks behind other G20 countries in terms of achieving climate change mitigation actions and targets. This includes resisting widespread adoption of renewable energies and leading in global coal exportation despite being one of eleven countries most severely impacted by rising global temperatures

(Climate Transparency, 2020). The international comparison further reveals that Australia's landscapes and human/non-human populations suffer from deforestation and pollution due to continued dependence on environmentally damaging and intensive food production practices (Roberts & Matto, 2018; Climate Transparency, 2020; UNEP, 2020).

As climate change research infiltrates global media and popular discourse, new technologies are changing global food production practices. Practices supporting economic sustainability/profit that address changing consumer preferences, while also considering climate change impacts, are emerging (Kelly & Rewhorn, 2019). Where production changes risk economic loss, however, few global examples exist that prioritise 'the environment' over human benefit. Much environmental production, for instance, is relegated to smaller, alternative farming models (Kelly & Rewhorn, 2019). In Australia, substantial pro-environmental action is necessary to regenerate land and return waterways to being self-sustaining systems having biodiversity indicators that meet pre-colonial settlement measures. Such actions cannot rely merely on technological advancments (Roberts & Matto, 2018), urban consumer preference changes (Kelly & Rewhorn, 2019), or improved data application, including big-data revolutions (Sarker *et al.,* 2019).

Australia is the only developed nation labelled as a deforestation hotspot. Unprecedented deforestation practices are being pursued to create pastures for the Australian meat and livestock sector that significantly contributes to climate change and greenhouse gas emissions. In America, technology and data have been instrumental in identifying locations most exposed to increased climate sensitivity and in need of varied agricultural production practices (e.g., crop types, irrigation) or policies (Ortiz-Bobea *et al.,* 2018). Agricultural technologies' ability to significantly mitigate climate change, however, necessitates a widespread social change to act upon environmental knowledge acquisition and behaviour modification recommendations valuing environmental sustainability. For example, although enforced legislation must accompany human food production changes, research shows that the social costs of pro-environmental actions are effective change-inducing agents. Agricultural irrigators sold water back to the government for environmental reasons because of social pressure from other irrigators promoting conformity (Haensch *et al.,* 2019). Changes in agricultural systems/practices demand a concerted global effort that takes sociological factors into account because, although human values persist over time (Stern, 2000), individual values can and do change to align with broader societal values.

Human values are defined according to what individuals consider important as they pursue goals and make decisions amongst behaviour options (Schwartz, 1994; Feather, 1995; Steg, Perlaviciute, *et al.,* 2014). Mounting research shows values affect individual behaviours, particularly pro-environmental actions (Ünal *et al.,* 2017; Maio, 2010; Crompton & Kasser, 2009; Rohan, 2000; Stern & Dietz, 1994; Dunlap *et al.,* 1983).

Moreover, individuals seek information aligned with their values (Steg, Goda *et al.,* 2014). Hence, relationships between knowledge acquisition and behaviour/actions are mediated by societal values. Theory and research show education alone insufficiently predicts healthy behavioural change. Health literacy research demonstrates knowing what causes ill-health, for humans and the environment, is not associated with health-promoting behaviour (Ragusa, 2020; Ragusa & Crampton, 2019). Theories about why individuals act upon health knowledge evidence information complexity (Ryan, 2009) and how information is framed or contextualised (Keyworth *et al.,* 2018; Lin & Yeh, 2017) matters. Further, self-conceptualisation and others' influence (Hoffman & Tan, 2015; Umberson *et al.,* 2010) affect behaviour, as does individual motivation by health prevention versus promotion (Keller, 2006), what stands to be gained or lost (Vezich, Katzman *et al.,* 2017), and risk perceptions (Bartels *et al.,* 2010).

Much of the research investigating what prompts human behaviour derives from consumer behaviour, health, and psychology research, not sociology. Meta-analyses show attitudes poorly predict healthy human behaviours (Keyworth *et al.,* 2018; Gallagher & Updergraff, 2012). While environmental attitudes determine pro-environmental behaviours more than environmental knowledge (Afroz *et al.,* 2015), environmental psychology finds that increased monetary cost widens behaviour-attitude pro-environment gaps (Mairesser *et al.,* 2012). For example, personal convenience affects pro-environmental behaviours such

as European car-sharing (de Luca & di Pace, 2015) and increased cost led to less environmentally friendly consumer behaviour, irrespective of pro-environmental sentiments or knowledge in Australia (Morgan, 2017).

Multi-disciplinary research and theory suggest global food and water security are possible if more environmentally sustainable practices are adopted. Nevertheless, defining, valuing, and actioning sustainable food production remains a socially complex issue that is dependent upon individuals' roles in production/consumption processes. The present research (conducted at an organisation that educates future primary producers, scientists, industry leaders, and consumers and values environmental sustainability) identifies what individuals consider to be the most pressing environmental sustainability issues affecting their lives related to food and water. The UNEP (2020) notes lifestyle choices globally impact greenhouse gas emissions. Amidst scientific research documenting food production (e.g. food miles, organic production processes) and dietary behaviours (e.g. low-carbon vegetarian/vegan diets) affect environmental sustainability (Harris *et al.,* 2019; IPCC, 2019), findings provide insights about pro-environmental literacy, personal behaviours/actions, and values for several agriculturally-intense products and issue awareness/salience to inform future pro-environmental change since research indicates agricultural illiteracy generally exists about individual food choice, production, and environmental impact connectivity (Clemons *et al.,* 2018).

## 2. Research Methods

### 2.1 Methodological Framework and Research Design

Methodologically, interdisciplinary investigations and theorisation about what prompts human behaviour inform the research design. Whereas historical health and science literacy research utilised a deficit model of learning, whereby individuals are presumed tabula rasa and awaiting fact-learning (Paloff & Pratt, 2001), the present design draws upon contemporary education and communication theory countering deficit theory's utility. Using social construction theory (Berger & Luckmann, 1991; Pinch & Bijker, 1987) may advance interdisciplinary research by arguing that in order to address global problems, including climate change, research must consider the social context and environment where issues arise, which demands attitudinal change and new knowledge acquisition/dissemination strategies to alter public issue (un)awareness (Bucchi & Trench, 2014; Kahan, 2015; Seethaler *et al.,* 2019). Social construction prioritises questioning why some issues are perceived as concerning, whilst others are ignored or invisible. In theorising reality-construction as a social process (Berger & Luckmann, 1991), this methodology overcomes deficit theory limitations because behaviour and attitudes are understood as driven more by values than facts. According to interdisciplinary science and technology studies (STS) purport, scientific facts and technologies require society's acceptance and validation of the natural/environmental and social order (Sismondo, 2007) achieved through co-construction (Taylor, 1995) and co-production (Jasanoff, 2004). Hence, changing environmental sustainability practices requires research and policy transcending the provision of more scientific/health information.

According to international research, environmental literacy/awareness fails to promote environmental action-taking, especially when economic and/or practical matters incentivise anti-environmental behaviours (Gould & Golob, 1998; Mairesser *et al.,* 2012; Pojani & Stead, 2015). Hence, social construction offers an alternative sociological conceptualisation to the psychological, educational, and health theorisation prominent in environmental change literature. Specifically, environmental sociology is a new specialisation theorising "human dimensions of environmental change" (Longo & Clark, 2016, p. 464) to transcend sociology's historical avoidance of environmental research or theorising. Reviews of environmental sociological research (Longo & Clark, 2016, p. 476) call for "a critical and integrative approach" to complement natural science research investigating environmental sustainability problems since industrialised agricultural production is fastidiously entwined with the social relations of an era (Foster *et al.,* 2010) and environmental sustainability encompasses both natural and human systems (Liu *et al.,* 2007).

The research design follows this methodological imperative, taking a critical, integrative approach to deepen understanding of knowledge, values, and behaviours related to food and water. Commencing from the premise that scientific facts play a limited


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role in predicting human behaviour without considering how the social reality of facts is constructed and embraced/rejected (Berger & Luckmann, 1991; Pinch & Bijker, 1987), this exploratory research adds to our understanding of what environmental sustainability concerns individuals know, or have, about food and water. The findings contribute to further documenting knowledge-action gaps apparent in psychological and health research and reveal knowledge deficits in agricultural production of sustainable food/water, which may be value-laden. By concurrently investigating knowledge, behaviours, and concerns, the study begins addressing calls for integrative environmental sociological research. Overall, the research aims to inform environmentally sustainable behavioural change and policy initiatives affecting food and water production/consumption to enhance agriculture and health systems/policy.

The research design utilises mixed methods to conduct an organisational study in the research location, the wheat-belt region of eastern Australia. As an investigation of employees' environmental sustainability awareness and activities, the research environment is a large, rural-regional organisation with sustainability values embodied in its mission statement promoting, "We are environmentally responsible and act in the best interest of the university and our communities" and "We consider the impact of our decisions on each other, our students, the environment, and our communities" (CSU, 2020). Specifically, the research design was created to explore what individuals environmentally value and what they know/do for a range of activities having scientifically documented negative environmental consequences related to food production, food consumption, and water usage. Prior to research commencement, university ethics committee approval for the conduct of human research was gained. All research instruments and processes received ethics clearance. Every participant was over age eighteen, willing and able to provide informed consent, and understood that their participation in the research would result no remuneration, nor advantage. Data collection costs were supported by a small university sustainability research grant and academic time buyout by the Institute for Land, Water, and Society. This article reports findings that answer five research questions:

1) How prominent are food and water amongst survey respondents' identification of the top three environmental sustainability issues affecting their lives? What are the sample's key food/water concerns?

2) Which of the food choices presented illustrate the sample's greatest/least environmental sustainability literacy about their agricultural production in Australia?

3) Are any demographic categories significantly associated with environmental sustainability literacy for the agricultural products surveyed?

4) Are individuals identifying food/water concerns as their key environmental sustainability issues more likely to correctly identify environmentally sustainable agricultural products?

5) Are individuals identifying food/water concerns as their key environmental sustainability issues more likely to engage in pro-environmental behaviours surveyed (i.e., avoid bottled water, use water refilling stations, choose water-friendly landscaping, participate in the meat-free week, shop at farmers' markets, buy locally produced vegetables, buy organic meat, or buy organic vegetables)?

### 2.2 Research sampling, instrument, and data analysis

Research sampling and instrument creation were informed by rurality's increased risk of experiencing poor health, disease, and unhealthier lifestyles compared with metropolitan locations (Alston *et al.,* 2019). Given the research population, members of a rural-regional Australian organisation, is highly geographically disbursed, and the research aimed to be an exploratory, mixed-methods organisational study, nonprobability sampling was selected (Neuman, 2014). A strength of this sampling method lies in its ability to maximise research participation and collect data from geographically disbursed individuals. Nonprobability sampling relies on individualistic desire to participate, which produces a non-random sample. Although the quantitative results are not generalisable beyond the research sample, they complement the deeper, personalised insights provided from the qualitative components of the research instrument

(Babbie, 2021).

Sampling and data integrity were assured by the research instrument, an online survey, requiring organisational members to enter their personal identification password and the system only accepting one survey submission per employee. Recruitment commenced by advertising research aims and participation details using the organisation's internal communication systems (e.g., online announcements, emails, noticeboards). The strengths of online surveying are, first, its anonymity and, second, its ability to collect more authentic data by minimising participants trying to please researchers, as found in face-to-face interviews by providing socially desirable responses (Johnstone & Hooper, 2016). Piloting the survey supported the instrument's reliability. Fifteen volunteers completed the pilot survey. This allowed every survey question to be scrutinised for ambiguity and definitional clarity, resulting in the modification of five questions. Measurement validity was supported by reviewing and refining all piloted close-ended questions for face and content validity (Polgar & Thomas, 2020). The validity of open-ended questions was determined by ensuring questions permitted for authentic self-expression of ideas and supporting authentication throughout data analysis (Neuman, 2014).

Research literature highlighting discrepancies between individual expression of pro-environmental sentiments and actions/behaviours informed the survey's content. Specifically, questions assessing environmental beliefs/concerns were posed after questions measuring behaviours. Thus, survey construction carefully considered how questions were ordered (i.e., when they appeared). This allowed qualitative questions about individuals' sustainability concerns to be captured without being biased by the survey's close-ended questions. For example, after demographic questions, the first substantive question asked was, "What do you consider to be the top three environmental sustainability issues affecting your life?" Free-text entry allowed up to 100-word descriptions for each issue, collected before encountering science/health literacy and action/behaviour questions. Hence, question-ordering minimised response bias.

This article presents results found from analysing four survey questions and demographic data. In addition to analysing the Environmental sustainability Issues question previously described, it analyses the question, "Which are environmentally sustainable food choices?", which has eight options (dairy products (milk, cheese, yoghurt); free trade coffee; farmed salmon; wild caught salmon; locally sourced lamb; organic beef; I don't know; none of these). Respondents were allowed to select multiple food-options, or I don't know or none. The third question analysed is, "In the past six months, how often have you done any of the following?" Answer categories (purchased bottled water; used water refilling stations; selected environmentally sustainable landscaping for home; shopped at farmers' markets; purchased locally produced vegetables; purchased organic meat; or purchased organic vegetables) simultaneously collected frequency data (never; 1-5 times; mostly; always) for every activity. Fourthly, this article analyses participation in, and/or awareness (yes; no) of, Meat-Free Week.

Data was entered into SPSS (27th version). After data cleaning to remove incomplete surveys, qualitative content analysis and quantitative analysis (descriptive and inferential statistics) were performed. Content analysis employed keyword (manifest) and contextual (latent) coding for all qualitatively provided environmental sustainability issues to capture all respondent-generated data about food and water. This dualistic coding approach produced an exhaustive list of categories relevant to the research questions (Babbie, 2021); if only manifest keywords (water, food) had been searched, then respondent-generated discussion of water/food related issues, such as drought, catchment, and crop production (in contexts meaningful to the environmental sustainability of food and water), would have been missed.

Finally, once all environmental concerns were coded, two major categories (Food-Concerns, Water-Concerns) were created, with 1=yes (concerned about the environmental sustainability of food), and 2=no (unconcerned). Missing data was excluded. Where respondents expressed concern about food and water (e.g., food sustainability with water scarcity as a major environmental sustainability concern), such data was coded in both major categories (Food-Concerns and Water-Concerns). For minor categories (e.g., those emerging within food/water), the dominant concern was coded. For example, the concern, Food security


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and the increased production of agricultural products in increasingly marginal climates, was coded Food Security, rather than Agriculture, to highlight the most pressing food/water-concerns visibility. The initial coding of respondents' concerns was reviewed and refined from cross-checking by the research team. This process assured final categories reflect respondents' most-pressing concerns and achieve the research's exploratory purpose (Polgar & Thomas, 2020). Direct quotes evidencing respondents' concerns appear as italicised text.

## 3. Results

### 3.1 Sample description

Descriptive details for the whole sample (n=412) appear in Table 1.

Most respondents were born in Australia and New Zealand (n=346/84.2%), with migrants derived from across the globe (Africa n=6/1.5%, Asia n=17/4.1%, Eastern Europe n=1/.2%, Western Europe n=28/6.8%, Middle East n=2/.5%, North America n=9/2.2%, South America n=2/.5%). Many respondents lived outside Australia for 10-49 years, with migrants staying in Australia for an average of 17 years. Four respondents (1%) did not specify their birthplace. Australians hailed from every state and territory. The majority of the sample were formally educated; 65% had at least a Bachelor's degree. Expectedly, since the research organisation was a university, 32% (n=134) held a Master's or Doctorate degree. Most (89%/n=363) had no formal environmental science education. Twice as many women participated than men, typical for survey research, and more (n=188/45.6%) held administrative than academic positions (n=134/32.5%). The remainder (n=90/21.8%) were retirees, adjuncts, and/or students. Overall, majority of the members (69%) were affiliated with the organisation for 1-10 years.

### 3.2 Environmental sustainability data

Fourteen percent (n=57) knew no agricultural food product (organic beef; locally sourced lamb; dairy products (milk, cheese, yoghurt); fair-trade coffee; farmed salmon; wild-caught salmon) provided for the question, "Which are environmentally sustainable food choices?" is environmentally sustainable in Australia. Salmon was the agricultural product most people (53%) considered sustainable; 9% (n=36) chose wild-salmon, 44% (n=182) farmed-salmon.

Thirty-five percent (n=144) chose organic beef, 34% (n=142) local lamb, 4% (n=17) dairy and coffee, and 2% (n=8) coffee alone as environmentally sustainable agricultural products. Education was the only significant demographic variable associated with this environmental sustainability literacy question; Having at least a bachelor's degree, in any specialisation, positively correlated with knowing none are environmentally sustainable food choices (.169, p=.001, n=405).

**Table 1.** Sample demographics

| Demographic Variable | Descriptive Data |
|---|---|
| Age | mean=42 (oldest=79, youngest=18) |
| Education | Bachelor's degree or higher (n=263/65%), Less than a Bachelor's (n=142/35%) |
| Environmental education | Yes (n=46/11%), No (n=363/89%) |
| Gender | Male (n=132/32%), Female (n=280/68%) |
| Organisational role | Full-time employee (n=268/65%), part-time employee (n=76/19%), Not employed (n=65/16%) |
| Nationality | Australian-born 90.5% (n=373), 1st Generation migrant 8.9% (n=37), Unspecified (n=2/.5%) |
| Years at organisation | <1 (n=51/12.4%), 1-3 (n=121/29.4), 3-5 (n=83/20.1%), 6-10 (n=80/19.4%), 11-20 (n=50/12.1%), >20 (n=15/3.6%), Unspecified (n=12/3%) |

This association was supported by Chi-Square, where c2 (1, N=405) = 11.62, p=.00. Those with at least a bachelor's degree tended to be older (.256, p=.000, r=402) and male (-.203, p=.000, r=401). None of the 46 respondents with formal environmental studies education correctly answered the question.

Content analysis revealed 45% (n=184) of respondent-generated environmental concerns related to water, compared with 22% (n=89) food. All Food/Water concerns were captured in thirteen categories (8 food, 5 water).

Figure 1 shows Food Security was the greatest Food-Concern; 38% identified issues related to producing enough food for humanity's growing population. Examples included population growth and food sustainability (e.g., growing enough to feed the growing population). Feeding has always been discussed in relation to feeding humanity, with concerns about producers' capacity to feed the human population as it increases rapidly over successive generations, and the inevitable shortfall in natural resources to support such production. Food Security concerns manifested about the environmental impact agricultural production poses on the natural environment.

The environment's limit to feed populations was not discussed relating to changes in natural landscapes or food security for other species. Rather, Food Security was discussed generally, understanding agriculture as a system where environmental sustainability concerns posed risks to the capacity for farming, land management, water availability, and sufficient environmental resources to adequately produce human food. Food Security concerns are also related to geography, namely global food security, the developing world, food security for third world countries, and enabling food security and the protection of important natural ecosystems in the developing world. Similarly, those concerned about Soil Quality noted that it was denuded, listing concerns about soil quality for farming/food production, the need for greater soil management and mineral depletion, the protection of soil fertility and protection from degradation, over-salinity, and, consequently, desertification [in] Australia and worldwide, Chernobyl, fertiliser runoff.
Whilst Agriculture and Environmentally Unsustainable Production could be collapsed into one category

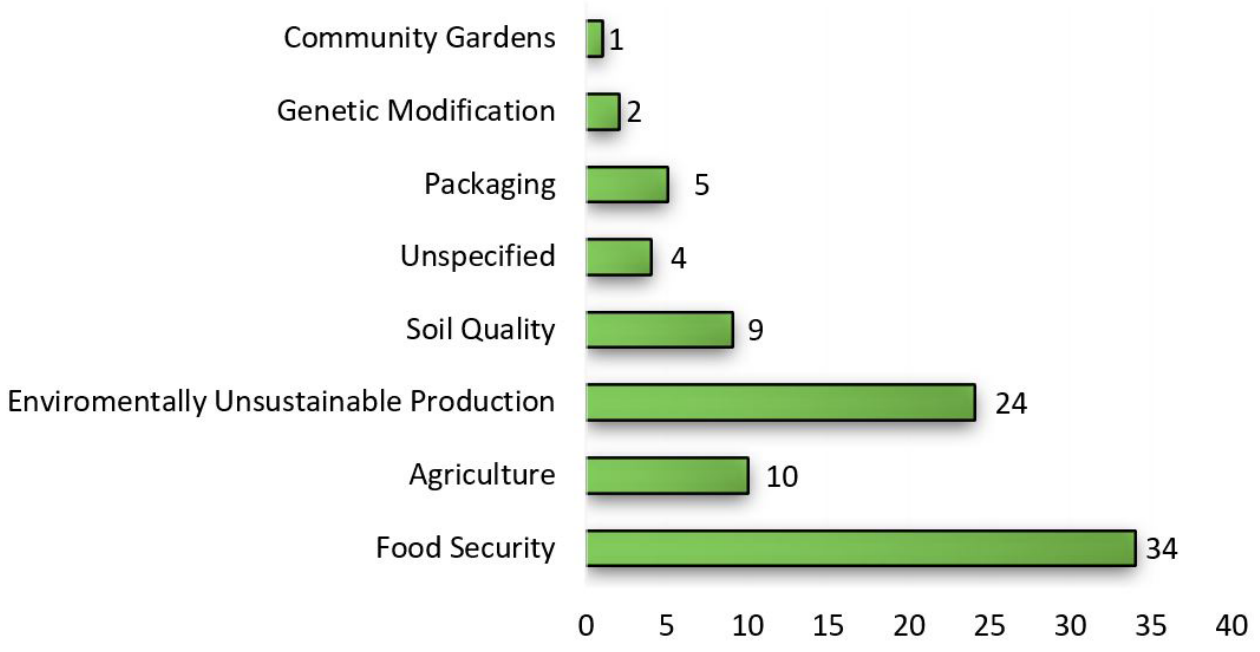


**Figure 1.** Enviromental sustaiability food concerns


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equal in size to Food Security, qualitatively, those listing agricultural issues specified the keyword "Agriculture" (e.g., sustainable agriculture, conventional agriculture, cold seam gas, and damage to agriculture). Contrastingly, respondents coded as Environmentally Unsustainable Production mentioned how the system of food production more generally fostered environmentally unsustainable practices. Examples in this category included unsustainable production practices, chemical use, throw-away society, meat production of cattle/sheep, Food miles – importing food from overseas, production and shipping of non-seasonal foods, and generally stating production. Only one respondent connected food production to environmental concerns affecting non-human species: deforestation, animal habitat loss, species loss, food production, land encroaching on animal conservation, and meat production. Insufficient Community Gardens also concerned one respondent, with gardening as an environmental sustainability concern related more commonly to food security, particularly individuals' need to achieve self-efficiency in food production/home gardens rather than rely on global or national food production systems.

A weak positive association emerged between Food-Concerns and Meat-Free Week (.187, p=.00, n=407) participation, supported by a chi-square significant association: c2 (1, N=407) = 14.165, p=.00. Figure 2 shows more (18%) individuals with Food-Concerns, compared to 6% without, engaged in Meat-Free Week.

Likewise, raising Food-Concerns for environmental sustainability reasons is weakly associated with the awareness that Meat-Free Week exists (.101, p=.05, n=409). Having Food-Concerns did not increase environmentally sustainable literacy (-.101, p=.05, n=412) about the food production practices in Australia investigated.

Analysis of the five food-related behaviours found most (83%) respondents did not regularly (>5x) shop at local farmers' markets or buy locally produced vegetables (59%). These behaviours were insignificant in comparison to having Food-Concerns. Contrastingly, buying organic vegetables (.133, p=.01, n=403) and meat (.182, p=.00, n=404), and having Food-Concerns correlated; Figure 3 illustrates many respondents purchased organic, yet those unconcerned about food for environmental reasons bought them more frequently.

This was supported by chi-square tests revealing significant associations between lack of Food-Concerns related to environmental sustainability and buying organic meat, c2 (3, n=404) = 13.453, p=0.00, or organic vegetables, c2 (3, n=403) = 7.554, p=.01. Overall, 19% (n=78) never bought organic vegetables (56%/n=229), compared with 37% (n=150) never purchasing organic meat. Education was the only demographic variable associated with organic food-buying behaviour; higher education weakly correlated with buying organic vegetables (.126, p=.05, n=396), but no corre-

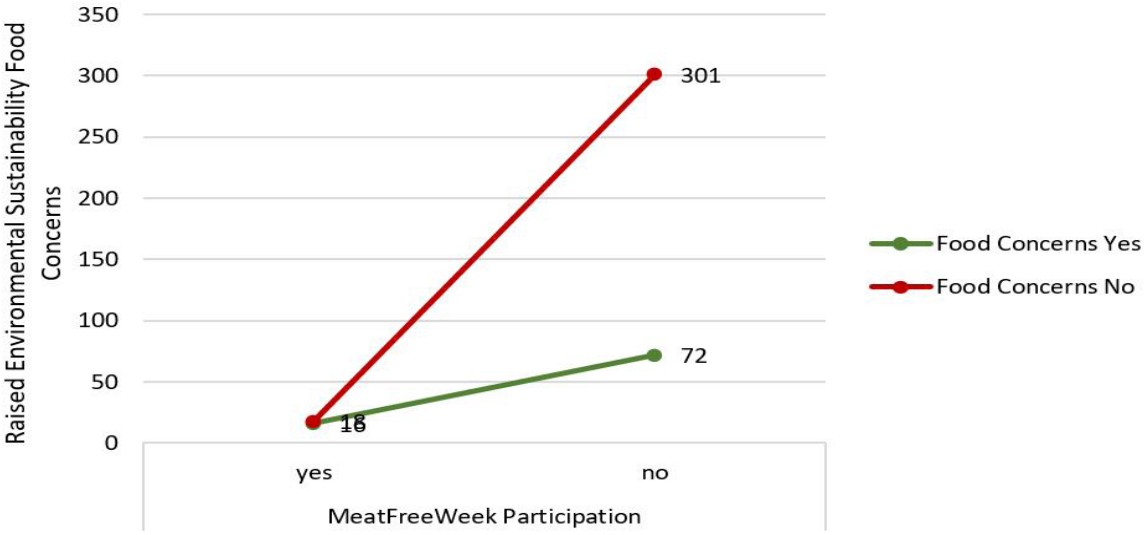


**Figure 2.** Food concerns and meat-free week participation

lation existed between higher education and buying organic meat.

More (45%/n=187) respondents had environmental sustainability concerns about water than food (22%/n=89). Figure 4 illustrates respondents' Water-Concerns.

The need for Water Conservation was the most common (15%) concern, followed by Unspecified (11%) or Pollution and Drinking Water Quality (11%) concerns. Fewest raised Ocean or Environmental (4%) or Rivers, including Catchment Management (5%), issues. Water-Concerns were not associated with awareness of Meat-Free Week, nor campaign participation. No demographic variables (Table 1) were significantly associated with having Water-Concerns. Respondents expressing Water-Concerns about the key environmental sustainability issue affecting their lives did not significantly differ from the rest of the sample's actions/behaviours for buying bottled water, using water refilling stations, or choosing environmentally sustainable landscaping at home.

## 4. Discussion and Conclusions

Amid any conceivable Environmental Sustainability issue survey, respondents could self-identify as affecting their lives, qualitative content analysis found a minority (22%/n=89) identified Food-Concerns. Research reports Australian urban consumer preferences shifting towards conscious-consumption food selection, namely heightened organic and local food interest and minimising supply chains (Kelly & Rewhorn, 2019). This study found Food-Concerns did not factor largely into respondents' awareness of, or actioning pro-environmental issues/behaviours, despite 45% (n=186) being born, or residing in, urban locations prior to affiliation with the rural-regional organisation researched.

The only food-related behaviours significantly associated with having Food-Concerns was buying organic meat and vegetables. Those most frequently buying organics, however, did not express environmental sustainability Food-Concerns. This suggests reasons beyond environmental sustainability underscore organic food purchases. Widely perceived human health benefits that organics are more nutritious (Ditlevsen *et al.,* 2018; Vigar *et al.,* 2019), despite empirical evidence (Vigar et al. 2019; Roberts & Mattoo, 2018), may explain this finding. Buying organics, however, is recommended to reduce individual carbon emission contributions (UNEP, 2020). Hence, findings show the need to increase environmental literacy given agricultural production's prominent role in environmental health or degradation (Roberts & Matto, 2018; Climate Transparency, 2020). This is particularly worthwhile since more respondents (45%/n=187) discussed Water-Concerns without mentioning in-

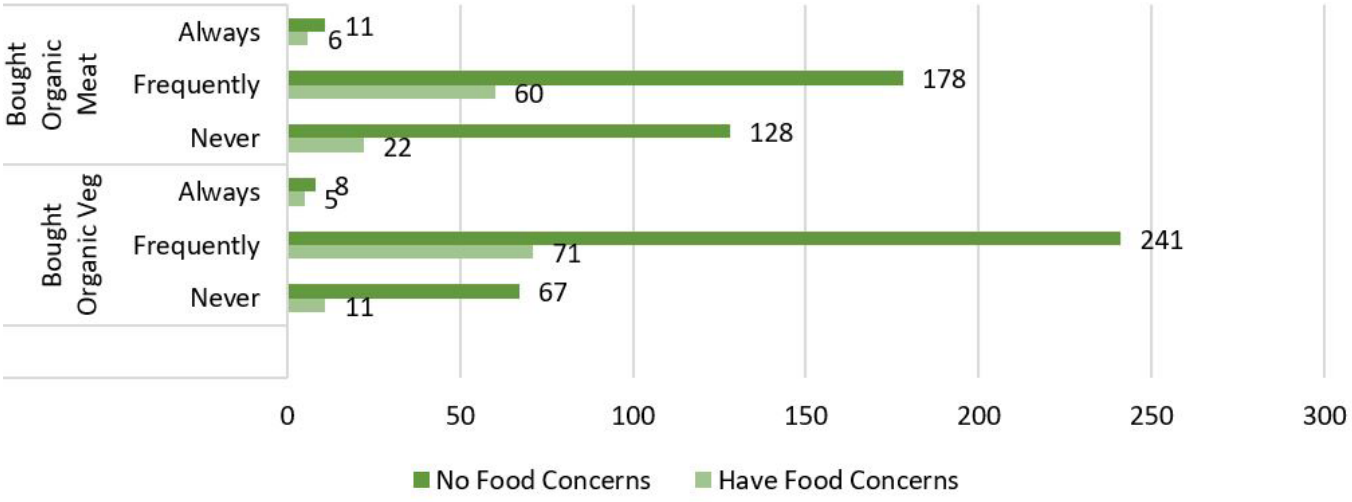


**Figure 3.** Enviromental sustaiability food concerns & organic purchasing behaviours


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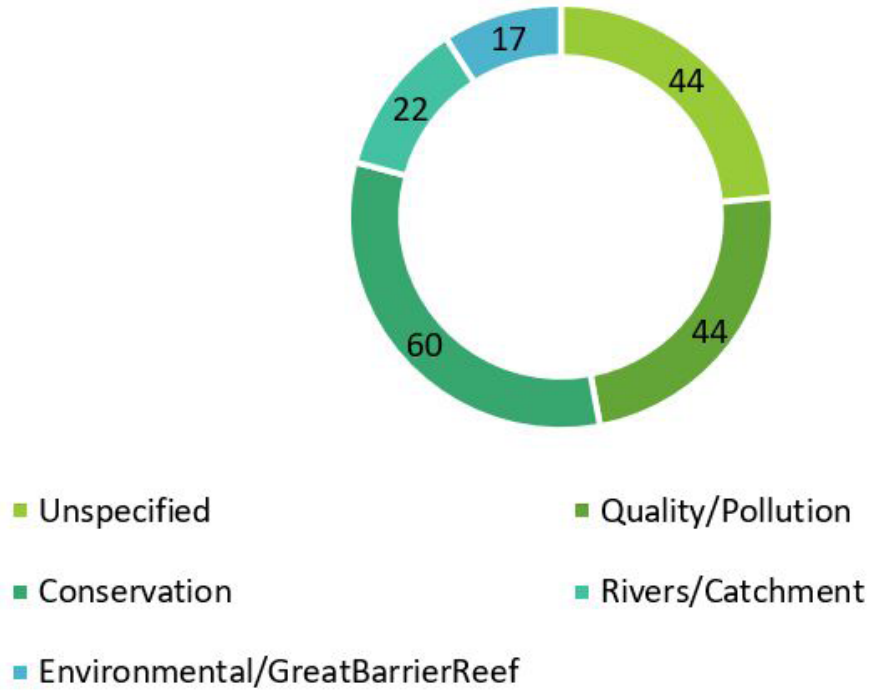


**Figure 4.** Enviromental sustaiability water concerns

dustrial production systems, including food/agriculture. Improving food-water security/health connections is necessary and supports environmental and sociological research evidencing industrialised agricultural production's entanglement with social norms, including environmental sustainability sociocultural perceptions (Longo & Clark, 2016; Foster *et al.,* 2010; Liu *et al.,* 2007).

Social psychology describes human values as driving individual decision-making/actions (Schwartz ,1994; Feather, 1995; Steg *et al.,* 2014). With 34 respondents (<1%) raising Environmentally unsustainable Production or Agriculture issues as key Food-Concerns, whilst 42% failed to regularly shop at farmers' markets, 46% never bought organic meat, and 30% never purchased organic vegetables (despite listing general environmental sustainability issues), shows limited social value or awareness exists about how agricultural production affects environmental sustainability. Social psychology finds individuals seek information aligned with their values (Steg, Goda, *et al.,* 2014).

Seeking environmentally sustainable agricultural production information thus appears devalued given the low environmental science literacy manifesting for food products; 8% knew no meat, dairy, or fair-trade coffee products were environmentally sustainable in the research location. Lack of knowing meat is unsustainable, whilst being affiliated with a rural-regional organisation in primary production landscapes is surprising given the agricultural sector's self-recognition that the industry is environmentally damaging. Extensive research documents the poor energy transition, water pollution/usage, and land degradation accompanying livestock production. For instance, more than two-thirds of the energy used to feed livestock soybeans and corn is wasted and supports water and land pollution (Kleinman *et al.,* 2018), contributing to greenhouse gas production (Climate Transparency, 2020).

No respondents with formal environmental science education correctly answered the environmental sustainability question about agricultural products. This may be partially due to the organisation's focus on river flows/catchment and natural resource management research, or alternatively reflect normative, sociocul-

tural biases disassociating or deemphasising human dietary choices with pro-environmental sustainability priorities. Global trends marketing plant-based diets for sustainability reasons (Fernandez, 2020; IPCC, 2019) remain marginalised in rural-regional Australia, supporting high meat and dairy production/consumption, despite the necessity for the agricultural industry and community change to support environmental sustainability (Beltran-Peña *et al.,* 2020). Respondents were concerned about poor agricultural conditions, namely poor soil or water shortages. The weak association between having Food-Concerns explicitly for Environmental Sustainability reasons and illiteracy about specific agricultural products' environmental impact, documents the need for scientific literacy about animal production and environmentally intensive crops, such as coffee. Findings further evidence consumer confusion around certification labels, specifically fair-trade coffee. The socio-economic benefits of fair-trade production come at the expense of environmentally sustainable production (Vanderhaegen *et al.,* 2018). Hence, clearer communication about industry priorities in sustainable production is required to improve transparency and accountability.

Valuing environmental sustainability differs from its enactment. Despite research documenting human values affect pro-environmental actions/behaviours (Ünal *et al.,* 2017; Maio, 2010; Crompton & Kasser, 2009; Rohan, 2000; Stern & Dietz, 1994; Dunlap *et al.,* 1983), listing Food/Water-Concerns as key Environmental sustainability Issues affecting one's life insignificantly affected the eight food/water behaviours investigated. Only completing higher education significantly increased environmental literacy. Research finds values/action gaps persist for environmental beliefs/behaviours (Mairesse *et al.,* 2012). Thus, investigating how knowledge about agricultural production's environmental impact affects environmental values and behavioural change remains pressing.

Overall, findings suggest the salience of costs, particularly social, affecting pro-environmental behaviour, such as encouraging agricultural irrigators to sell water back to the government for environmental reasons (Haensch *et al.,* 2019), requires further research. Likewise, if higher commodity prices (Morgan, 2018; Mairesser *et al.,* 2012) decrease pro-environmental actions and how much consumers will pay for environmentally sustainable food production/food security, compared with agricultural costs (Kleinman *et al.,* 2018) remains necessary given respondents' reported low organics buying despite raising food production concerns about soil salinity, agricultural runoff and chemical usage, packaging, food mileage, genetic modification, and food security to feed growing human populations worldwide.

Respondents were concerned about agriculture production and food security to support humanity's sustainability, not sustainability for the environment or non-human species. Focus on global food security coincides with Australia's reputation as a food-secure country continuing abundant production, despite a severe drought, ranking in the top ten nations for food affordability and availability, lowest for undernourishment, and high (70%) exportation of food produced (ABARES, 2020; Beltran-Peña *et al.,* 2020). Queensland research shows even low socioeconomic households in Brisbane report low food insecurity (<20%), less than similar American households (McKechnie *et al.,* 2018). The present sample's high education (65% have at least a bachelor's degree) and low environmental concern and literacy about national agricultural production impacts/issues, including food security (whilst those having Food Security concerns focused on human-centred issues), further Tasmanian survey research finding higher socioeconomic status and university-educated individuals less likely to consider food security an issue (Kent *et al.,* 2020). This literature does not investigate nutritional aspects of food choices or economic realities that quality Australian food (i.e., fresh produce, quality protein sources, etc.) is more expensive. Hence, future food security research is needed to see if highly nutritious agricultural products produced in environmentally sustainable ways affect affordability perception. Such investigation would determine if food security perceptions reflected illiteracy about Australian agricultural production intensification driven by "the financial bottom line" with "little factoring of environmental and social costs" (Kelly & Rewhorn, 2019, p. 122).

Meat-Free Week participation's positive association with having Food-Concerns, without significant association manifesting for any demographics (age, gender, education) or those reporting Water-Concerns, suggests less awareness/concern about the role meat production plays in environmental sustainability. No respondents raised Water-Concerns related to animal-based food production systems. Water-Concerns


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about quality/scarcity manifested as drought and natural resources requiring physical and political management. Catchment and reliance on river water for mains water on the Murray River example implicitly connected water health to agriculture and natural environment sustainability. The research location long exhibits tension about river water flows determining the quality and quantity of water/food production and environmental assets (Murray-Darling Basin Authority, ND). Although 45% of respondents listed Water-Concerns as key environmental sustainability issues affecting their lives, the qualitative analysis found concerns were vague or pollution/production-directed. Four percent of Water-Concerns considered water for the environment. Having Water-Concerns failed to correlate with demographics or water-conserving behaviours (home landscaping choices, food purchasing/consumption decisions, and water purchasing/consumption actions such as refilling water bottles/buying bottled water). Expressing concerns, without translating concern into action, is consistent with growing literature examining the impacts values/attitudes have, or fail to have, on behaviour/action-taking (Wolters *et al.,* 2019).

Quantitative determination of what changes are necessary to meaningfully address Water-Concerns related to the environment, agricultural production, and food/drinking water behaviours affecting production/consumption practices is needed because this study's findings are exploratory and non-generalisable. Future researchers may build upon the Food/Water-Concerns found by investigating willingness to pay (Wolters *et al.,* 2019) and perceived convenience (Morgan, 2017; de Luca & di Pace, 2015), factors intervening with ideological value-expression. Further, individual willingness to change, particularly by primary producers, requires policy support. American agriculture and climate sensitivity research found water use/access (e.g., irrigation practices) required policy change to allow crop specialisation shifts in responding to climate changes affecting food production (Ortiz-Bobea *et al.,* 2018). With over 70% of global freshwater used for crop irrigation, and the negative environmental impact of intensive agribusiness, and its irrigation, create (Roberts & Mattoo, 2018; Harris *et al.,* 2019; Courard-Hauri, 2020; IPCC, 2019), however, personal willingness may become irrelevant if environmentally sustainable agricultural practices become physically necessary.

Finally, this study furthers research (Paillé *et al.,* 2020; Dzhengiz & Niesten, 2020) arguing knowledge acquisition is needed to facilitate the societal transition towards environmentally sustainable action-taking, driven by organisational and/or personal values. Although respondents were highly educated, knowledge specialisation may explain why, as others have found, even highly educated individuals fail to identify environmentally sustainable options (Vicente-Molina *et al.,* 2013). Likewise, having environmental concern/awareness did not necessarily promote pro-environmental action-taking (Helm et al. 2018). What nationally, and globally, prevents environmental knowledge transfer from scientists to broader populations urgently is required because a sizable literature documents traditional agriculture negatively affects the environment and quantity/quality of water/land utilised, and wildlife's future (Harris *et al.,* 2019; Courard-Hauri, 2020; IPCC, 2019). Improving public science/health literacy about relationships between water/food scarcity, agricultural production, and true costs is vital since long-term environmental gains demand broad stakeholder participation from producer to consumer, council to composter (IPCC, 2019).

## Conflict of interest

The authors declare no conflict of interest

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# Deciphering consumer purchase intention towards red palm oil as functional food: evidence from Malaysia

**PEI-TING TAI[1], YEN-NEE GOH[1*], MAO-SENG TING[2]**

[1]Graduate School of Business, Universiti Sains Malaysia, Penang, Malaysia
[2] School of Business Management, Han Chiang University College of Communication, Penang, Malaysia.

* Corresponding author: yngoh@usm.my

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Functional food, Purchase intention, Theory of Planned Behaviour (TPB), Malaysia, Red Palm Oil

This study aims to identify the determinants influencing consumer purchase intention toward red palm oil as a functional food with the application of an extended Theory of Planned Behaviour (TPB) among Malaysian consumers. A total of 370 data were collected via mall intercepts in Malaysia using convenience sampling. Partial least squares (PLS) analysis was used to evaluate the measurement and structural model of the study. The results demonstrated that attitudes, subjective norms, and perceived behavioural control have a positive and significant relationship with the purchase intention of red palm oil as a functional food. Additional variables like food involvement, environmental concern, perceived value, and perceived risk significantly affect consumers' purchase intention of red palm oil as a functional food. Surprisingly, there is no relationship found between food neophobia and healthy lifestyle purchase intention. The results showed that TPB constructs confirmed its explanatory influence on purchase intention and an extended TPB model with additional variables demonstrated a superior explanatory interpretation of the purchase intention of red palm oil as a functional food. This paper concludes with implications and limitations of the study, as well as suggestions for future research.

## 1. Introduction

Nowadays, healthy food consumption has become a norm since consumers are getting more health-conscious and pay close attention to healthy food choices, such as functional food. Functional food could be defined as "natural or processed foods that contain known or unknown biologically active compounds, which, in defined, effective non-toxic amounts, provide a clinically proven and documented health benefit for the prevention, management, or treatment of chronic disease" (-Martirosyan and Singh, 2015, p.215). According to Alongi and Anese (2021), functional food could be described as "food products that provide a specific health benefit, beyond basic nutrition". Needless to say, healthy food choices such as consuming functional food play an essential role in reducing the risk of chronic diseases (Provencher & Jacob, 2016) besides providing necessary nutrition for the benefit of consumers (Elsohaimy et al., 2015). Examples of functional food include quinoa seeds, oats, wheat, sprout, fibre, modified oil, food fortified with vitamins (Elsohaimy et al., 2015; Pasko et al., 2014), and red palm oil. Among the functional food, much of the functional food rich in multiple nutritious values such as vitamin E and saturated fatty acids was prepared using red palm oil (Palm Oil Health, 2019). Red palm oil contains 20 different types of beta-carotene, which is also known as the fount of natural plenty with mixed carotenes (Chin, 2019). According to Clemens

et al. (2017), dietary red palm oil enhances functional recovery in heart and brain diseases.

Malaysia is one of the biggest producing countries of palm oil (MPOC annual report, 2020). Based on the annual report (2020) available from the Malaysian Palm Oil Council (MPOC) website, revenue from exports of palm oil products increased by RM9.3 billion (14.6%) to exceed RM73 billion in 2020. Malaysian palm oil has received worldwide acceptance in which its specific properties could be used in a wide range of food products (Tan et al. 2021). For example, red palm oil as the cooking oil is one of the common applications of red palm oil in food products. As argued by Tan et al. (2021), at present, "red palm oil is still gaining acceptance" in the market. As stated by the Ministry of Plantation Industries and Commodities Malaysia, red palm oil would continue to be promoted to consumers considering its health benefits. Consumers who are practicing healthy lifestyles or those who are more health-conscious will have a favourable evaluation of red palm oil as a functional food. This also demonstrated that red palm oil as a functional food has great potential to promote healthy food consumption among consumers. With this in mind, an investigation of the consumer purchase intention toward red palm oil as a functional food is timely and relevant.

A growing body of literature has examined consumer purchasing intention towards different types of functional foods in Malaysia, such as natural functional foods (Rezai et al. 2017) and general functional foods (Febian et al. 2021). However, far too little attention has been paid to red palm oil as a functional food. While the consumption of functional food prepared with red palm oil has very high nutritional benefits for consumers (Loganathan et al., 2017), there is still insufficient data to understand consumers healthy food choices especially in choosing red palm oil as a functional food. Researchers have not considered red palm oil as a functional food in the consumer behaviour context.

Hence, the major objective of this study was to investigate the determinants influencing consumer purchase intention toward red palm oil as a functional food with the application of an extended Theory of Planned Behaviour (TPB) among Malaysian consumers. Drawing upon the stated objective, this study attempts to examine whether TPB constructs could be extended with additional variables namely, food involvement, food neophobia, environmental concern, healthy lifestyle, perceived value, and perceived risk on consumer purchase intention towards red palm oil as a functional food. This study provides an exciting opportunity to advance our knowledge of potential determinants that influence consumer purchase behaviour concerning red palm oil as a functional food in the Malaysian context. For practitioners, this study helps to provide necessary insights that could help in developing a strategic marketing plan to promote the use of red palm oil as a functional food that encourages healthy eating habits.

## 2. Literature Review and Hypotheses Development

The theory of Planned Behaviour (TPB) model explained the influence of attitude, subjective norm, and perceived behavioural control on behavioural intention to perform a behaviour (Ajzen, 1991). Attitudes refer to the degree of favourable level or evaluation towards action or behaviour (Ajzen & Madden, 1986). Subjective norm refers to perceived social pressure from the environment exposed to an individual, they should either perform the specific behaviour or not (Ajzen, 1991). Perceived behavioural control refers to individual abilities to facilitate own perception of control towards behaviour by owning resources or opportunities to perform the act. Thus, for individuals who have more control and power to act a specific behaviour toward an object, their intention to buy that object will be high (Shin & Hancer, 2016). According to Kumar and Smith (2017), TPB is suitable and broadly applied in food-related studies. Scholars have suggested an extended TPB in food consumption studies for a better explanatory (Imani et al. 2021). Hence in this study, we have adopted the original TPB constructs with additional variables that include food involvement, food neophobia, environmental concern, healthy lifestyle, perceived value, and perceived risk on consumer purchase intention towards red palm oil as a functional food (see Figure 1).

According to Bell and Marshall (2003, p.236), food involvement could be defined as the level of involvement that is assigned as a personality characteristic of the individual toward the food. Food involvement is positively related to the level of engagement and the person's feelings toward the food (Farragher et al.,

2016). Food involvement is determined by the level of importance of foods for a person and enjoyment when a person expresses foods (Yangui et al., 2016). Consumers who are highly involved with food tend to choose more healthy food alternatives (Moons et al. 2018; Farragher et al., 2016). Bell and Marshall (2003) also argued that consumers who are highly engaged with food will have a higher tendency to try so-called "novelty" food, innovative food, healthy food, or functional food. Based on the above viewpoints, the following hypothesis is being proposed below:

**H1.** Food involvement has a positive effect on the purchase intention of red palm oil as a functional food.

Food neophobia has also been revealed to have a detrimental impact on consumers' purchase intention of newly launched functional food products containing unknown or unusual ingredients (Moons et al., 2018). Humans are more afraid of uncertainty, especially when it comes to food, and they prefer to buy known foods than novel or unusual foods (Verbeke, 2015).
Similarly, the higher degree of awareness of environmental issues like food containing pesticide, genetic modification, and health effects influence consumers to shift their consumption patterns to healthy food like organic food (Loizou et al., 2013). The consumer with a higher degree of food neophobia would be less likely to consume functional foods or not even give them a try to these foods (Stratton et al., 2015).
A study by Mak et al. (2017) confirmed neophobia to be negatively correlated with food consumption intentions. Hence, the following hypothesis is proposed below:

**H2.** Food Neophobia has a negative effect on the purchase intention of red palm oil as a functional food
Based on Yadav and Pathak's (2016) study, environmental concern is directed at the awareness of people towards the environmental issue and provides ways to resolve the issue being raised. Environmental concern is an important predictor that influences a consumer to change to better food consumption habits that have minimal effect on the environment (Moons et al., 2018). In a study by Imani et al. (2021), it was found that environmental concerns affect the intention to buy organic products significantly. According to Saleki et al. (2019), consumers preferred to buy ecological products that do not damage the environment. After all, consumer decision-making was greatly affected by integrating those concerns, which was derived from consumers' tendency to consume red palm oil as a functional food. Thus, the discussion results in the following hypotheses:

**H3.** Environmental concern has a positive effect on the purchase intention of red palm oil as a functional food.

Some studies argued that the lifestyle of consumers affects their reaction and consumption pattern towards healthy products. For example, Küster-Boludaa and Vidal-Capilla (2017) argued that consumers who perceive a healthy lifestyle as an important goal for their day-to-day life are more willing to consume healthy foods. As a result, particularly health-conscious consumers are more inclined to purchase healthy food products (Miklavec et al., 2015) such as red palm oil as a functional food. Thus, we claim that consumers' healthy lifestyle influences their purchase intention of red palm oil as a functional food. Hence, this study proposed:

**H4.** Consumers' healthy lifestyle has a positive effect on the purchase intention of red palm oil as a functional food.

According to Wang and Hazen (2016), perceived value is the products' ability that meets consumers' needs in terms of their quality, cost, and nutritional elements. An inspiring role in the market is a place where perceived value regularly takes place. Customers' purchase intention will be increased when they perceive the product's value or service as higher than alternative products. The perceived value of palm oil is useful for several purposes, from skincare to hair treatment, and the most important benefit for health, helping reduce cardiovascular disease (Clemens et al., 2017). It is often suggested that the enhancement of nutrition knowledge significantly contributes to accepting functional food. Thus, Hypothesis 5 is proposed as follows:

**H5.** Perceived value has a positive effect on the purchase intention of red palm oil as a functional food.

Perceived risk is defined as any decision of buying a product that might have an unpleasant experience, financial loss, or be unsafe for consumers' health (Bhukya & Singh, 2015). This study defines a product


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that is judged to be risky to consume, which results in negative effects on consumers' health that might influence their tendency to buy that product. Hence, the relationship between perceived risk and functional food purchase intention using red palm oil is negative. If a product is judged to have a lower possibility to be risky, then the outcome of consumer purchase behaviour was positive, resulting in a higher tendency to purchase that product (Markos et al., 2018). Unknown products directed consumers to perceive a high degree of risk when making a purchase decision as they have little knowledge of the unknown food/ingredients, such as functional food. Therefore, the following hypothesis is submitted:

**H6.** Perceived risk has a negative effect on the purchase intention of red palm oil as a functional food.

One of the essential elements of the theory of planned behaviour is the attitude, which means a person's reaction is based on positive or negative feelings towards an object (Ajzen, 1991). Understanding how a person feels toward buying a product or using a service is based on their expectation and evaluation of the product or service (Ajzen & Fishbein, 1980). A positive attitude influences the intention to purchase (Imani et al. 2021). A favourable evaluation and a positive belief that the food is healthier tend to increase an individual's intention to purchase (James et al. 2019). According to Lim and Goh (2019) and Küster-Boludaa & Vidal-Capilla (2017) research, attitudes show a significant positive relationship with purchase intention. From the study of Ajzen (1991), when a person has a favourable attitude toward the product, they will be more likely to perform the behaviour to buy that product. Thus, Hypothesis 7 is proposed as follows:

**H7.** Attitude has a positive effect on the purchase intention of red palm oil as a functional food.

The second element in the theory of planned behaviour is the subjective norm, which explains a person's behaviour based on others' behaviour. A person's decision-making is mainly influenced by the people around them and others' social pressure (Ajzen & Fishbein, 2010; Teng & Wang, 2015; Lim & Goh, 2019). That means family members and friends who always buy healthy products might influence a person's purchase intention (Pedersen et al., 2015). As a result, if someone close to them believes that functional food is good for health, they will have a high intention to buy that functional food. If, on the other hand, someone close to them believe that functional food is bad for their health, they will be less likely to purchase functional foods (Ghvanidze et al., 2016). Functional food using red palm oil is recognised as healthier and better food and environmentally friendly (Chin, 2019). Therefore, when people around them, who are important for them, believe that functional foods made with red palm oil are far superior than regular foods, the following can be hypothesised:

**H8.** Subjective norm has a positive effect on the purchase intention of red palm oil as a functional food.

There is one more element in the theory of planned behaviour, which is known as perceived behavioural control. It refers to the degree of ability of a person to have more control over the desirability to consume and purchase whatever they prefer (Quevedo-Silva et al., 2016; Vabo & Hansen 2016). If the buying process of a product is perceived to be easy to execute, there is a high tendency to buy that good (Quevedo-Silva et al., 2016). Ajzen and Fishbein (2005) also found that more resources and opportunities to buy a product will increase the intention to perform that behaviour. Thus, if consumers perceive to have more control over purchasing functional food using red palm oil, their purchase intention towards functional foods using red palm oil will be high. Hence, Hypothesis 9 is suggested as below:

**H9.** Perceived behavioural control has a positive effect on the purchase intention of red palm oil as a functional food.

## 3. Materials and Methods

### 3.1 Data collection procedure and sample size

Data were collected through the distribution of questionnaires via face-to-face interviews and self-administrated by the respondents in crowded shopping malls in Malaysia. In this study, respondents were briefed on the benefits of red palm oil as a functional food. A cross-sectional survey employing a convenience sampling technique is used. Potential respondents were required to answer two screening questions, whether

they were Malaysian and aged above 21. This survey yielded 370 valid (usable) responses. Based on the 10 times rule proposed by Barclay et al. (1995) and Chin and Newsted (1999) for acceptable minimum sample size, 370 is considered to be acceptable for PLS analysis. In this study, SPSS and Smart PLS 3.0 (Ringle et al., 2015) were used for data analysis. The respondent profile is summarised in Table 1.

### 3.2 Measurement of the variables

The measurement used in this study is adapted from past empirical studies. The sources of adapted items are stated in Table 2. All measurements applied a five-point Likert scale (1= strongly disagree to 5 = strongly agree) except purchase intention with a seven-point Likert scale (1= strongly disagree to 7 = strongly agree). Forty-three measurement items were adapted from various resources of previous studies were consisted of the ten constructs (see table 2).

## 4. Results

### 4.1 Testing for common method variance

Before data analysis, common method variance testing (Simmering et al., 2014) was conducted. The result showed that the R square with marker variable and without marker variable for the dependent variable (purchase intention) has the same R square value of 0.486, which is a 0% increment. Thus, common method variance is not a significant problem in this study.

### 4.2 Measurement model analysis

Hair et al. (2017) highly recommended that a study should run a convergent validation. It is used to check the validity of the results generated with the representative sample within the population. Hair et al.'s (2017) guidelines for indicator loading, average variance extracted (AVE), and composite reliability (CR)

**Table 1:** Demographic profile of respondents (N = 370)

| Variable | Frequency | % |
|---|---|---|
| Gender | | |
| Male | 121 | 32.7 |
| Female | 249 | 67.3 |
| **Age** | | |
| 21 – 25 years old | 154 | 41.6 |
| 26 – 30 years old | 93 | 25.1 |
| 31 – 35 years old | 63 | 17.0 |
| 36 – 40 years old | 29 | 7.8 |
| 41 – 45 years old | 25 | 6.8 |
| Above 46 years old | 6 | 1.6 |
| **Nationality** | | |
| Malaysian | 370 | 100 |
| **Occupation status** | | |
| Full-time (work more than 30 hours a week) | 262 | 70.8 |
| Part-time (work between 8-30 hours a week) | 9 | 2.4 |
| Student | 94 | 25.4 |
| Unemployed | 5 | 1.4 |
| **Education level** | | |
| Secondary school | 4 | 1.1 |
| Certificate/ Diploma | 45 | 12.2 |
| Bachelor's Degree | 277 | 74.9 |
| Master's Degree | 43 | 11.6 |
| Others | 1 | 0.3 |


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are above 0.70, 05, and 0.7, respectively. Based on the results, all the items were having factor loadings higher than 0.70 except FN1, HL3, PBC3, and PBC4. Those loading scores were between 0.5 to 0.69 and the items were kept because the latent variable fulfilled the AVE criteria (Hair et al., 2017). However, two measurement items, FI2 and FN3, were deleted due to loading less than 0.4. In terms of AVE value, all the items were found to meet the minimum value requirement of 0.50. The CR values were also found to be greater than 0.70, ranging from 0.752 to 0.931 (see Table 2). Then, discriminant validity was assessed. According to Hair et al. (2017), discriminant validity involves determining if each of the components differ from other constructs within the proposed model. In this study, discriminant validity was verified by adopting Heterotrait – Monotrait (HTMT). The HTMT value should be smaller than the HTMT value of 0.85 (Kline, 2011). Table 3 demonstrated that all the values were less than HTMT.85, indicating that discriminant validity was proven in this study.

### 4.3 Structural model analysis

In the next stage, this study analysed the structure model result. Hair et al. (2017) applied the bootstrapping technique to figure out the statistical significance. Based on a one-tailed test with 5000 bootstrapping procedures, the variance explained for purchase intention is 48.6% (R2 equal to 0.4486) for all independent variables. Table 4 shows how consumers' purchasing intentions for functional foods containing red palm oil are influenced by food involvement (FI) and environmental concern (EC).. Hence, H1 ($\beta = 0.088$, $p = 0.05$) and H3 ($\beta = 0.095$, $p < 0.05$) were both supported. However, food neophobia (FN) and healthy lifestyle (HL) had no effect on consumers' purchase intentions for functional foods containing red palm oil. Thus, H2 ($\beta = -0.046$, $p > 0.10$) and H4 ($\beta = -0.022$, $p > 0.10$) were not supported. According to H5, the relationship between perceived value (PV) and purchase intention of functional food containing red palm oil was supported as ($\beta = 0.099$, $p < 0.10$). As a result, H5 was supported. Whereas H6 and H7 were also supported. Perceived risk (PR) ($\beta = -0.070$, $p < 0.05$) and attitude (ATT) ($\beta = 0.312$, $p < 0.05$) influences the consumers' purchase intentions toward functional food containing red palm oil. Meanwhile, subjective norm (SN) influences consumers' purchase intention as well. Thus, H8 was supported ($\beta = 0.099$, $p < 0.10$). In terms of H9, perceived behavioural control (PBC) influences consumers' purchase intentions of functional foods containing red palm oil. Therefore, H9 was found to be supported ($\beta = 0.085$, $p < 0.10$). In Figure 1, the results of path coefficients are illustrated.

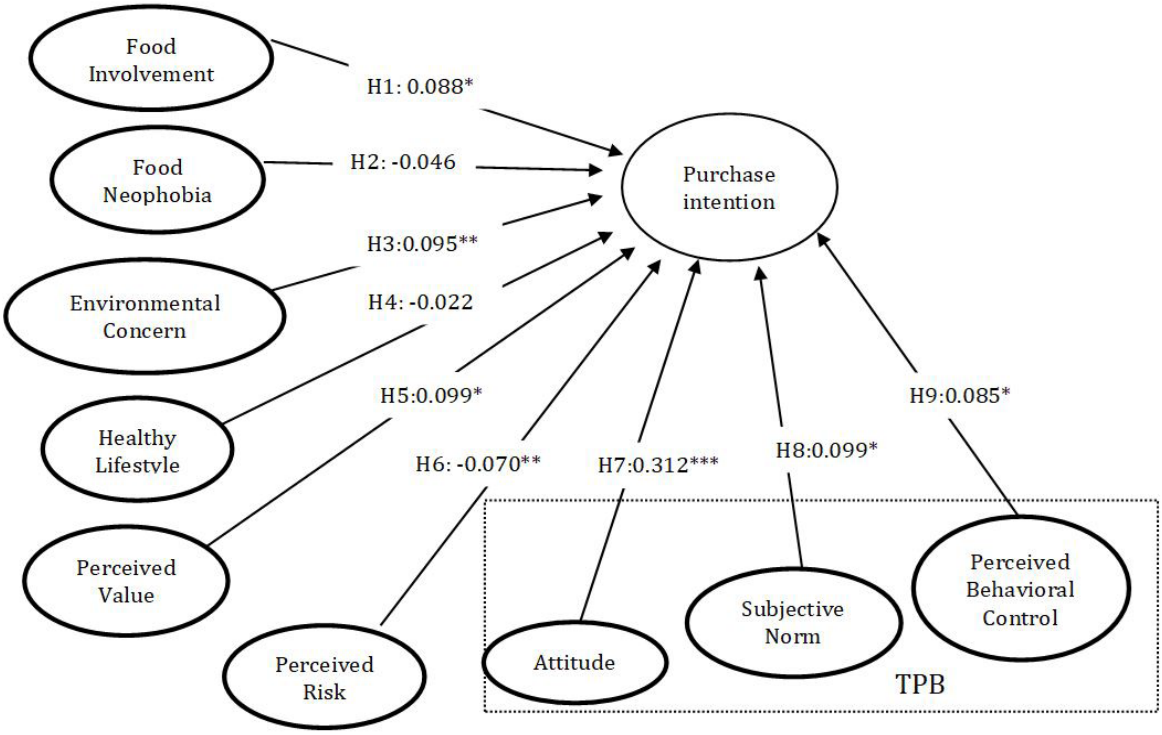


**Figure 1.** Research model

**Table 2.** PLS result of convergent validity

| Latent variable | Measurement Item | Loading | CR [a] | AVE [b] |
|---|---|---|---|---|
| Food Involvement | FI1: Mainly, I eat healthy food. | 0.702 | 0.789 | 0.556 |
| (Yangui *et al.*, 2016) | FI3: The food accounts for a significant part of the family's traditions. | 0.785 | | |
| | FI4: The food is a link to provide information about other cultures. | 0.747 | | |
| Food Neophobia | FN1: Exotic food seems strange to me. | 0.539 | 0.752 | 0.509 |
| (Moons *et al.*, 2018) | FN2: At dinner parties, I will try new food. | 0.786 | | |
| | FN4: I like trying out restaurants where they serve food from everywhere. | 0.787 | | |
| Environment Concern | EC1: The balance of nature is very delicate and can be easily upset. | 0.716 | 0.880 | 0.649 |
| (Yadav & Pathak, 2016) | EC2: Human beings are severely abusing the environment. | 0.812 | | |
| | EC3: Humans must maintain a balance with nature to survive. | 0.834 | | |
| | EC4: Human interferences with nature often produce disastrous consequences. | 0.853 | | |
| Healthy Lifestyle | HL1: I participate in physical activities 30 minutes five to seven days a week. | 0.739 | 0.832 | 0.555 |
| (Küster-Boludaa & | HL2: I eat two pieces of fruit a day. | 0.820 | | |
| Vidal-Capilla, 2017) | HL3: I eat vegetables every day. | 0.658 | | |
| | HL4: Normally, I avoid foods high in fat and calories. | 0.754 | | |
| Perceived Value | PV1: Buying functional food using red palm oil can lower purchase costs. | 0.771 | 0.897 | 0.687 |
| (Wang & Hazen, 2016) | PV2: Compared to other food, functional food using red palm oil has a better cost ratio. | 0.867 | | |
| | PV3: Compared to other food, buying functional food using red palm oil can lead to resource and energy savings. | 0.873 | | |
| | PV4: Buying functional food using red palm oil can reduce harmful effects on the environment. | 0.799 | | |
| Perceived Risk | PR1: I am afraid that the performance of functional food using red palm oil is inferior. | 0.865 | 0.906 | 0.707 |
| (Wang & Hazen, 2016) | PR2: I am afraid that functional food safety using red palm oil is inferior and there are potential safety risks. | 0.871 | | |
| | PR3: I am afraid that functional food's performance using red palm oil would cause indirect finance loss. | 0.842 | | |
| | PR4: I am afraid that functional food's quality warranty using red palm oil is not good. | 0.783 | | |
| Attitude | ATT1: Functional food using red palm oil is safer to eat. | 0.883 | 0.918 | 0.738 |
| (Haque *et al.*, 2015) | ATT2: Functional food using red palm oil is healthier to eat. | 0.902 | | |
| | ATT3: Functional food using red palm oil is tastes better. | 0.766 | | |
| | ATT4: Functional food using red palm oil has superior quality. | 0.878 | | |

*Note: FI2 and FN3 were deleted due to low loading, [a] Composite Reliability (CR) [b] Average Variance Extracted (AVE)*


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**Table 2.** PLS result of convergent validity (continue)

| Latent variable | Measurement Item | Loading | CR [a] | AVE [b] |
|---|---|---|---|---|
| Subjective Norm | SN1: My family thinks I should consume functional food using red palm oil. | 0.831 | 0.881 | 0.649 |
| (Teng & Wang, 2015) | SN2: My friends think I should consume functional food using red palm oil. | 0.866 | | |
| | SN3: News and magazines affect my purchase decisions to consume functional food using red palm oil. | 0.763 | | |
| | SN4: Government supports for functional food affects my decisions to consume functional food using red palm oil. | 0.758 | | |
| Perceived Behavioural | PBC1: I am confident that I could purchase functional food using red palm oil if I want to. | 0.849 | 0.832 | 0.557 |
| Control (Shin & Hancer, | PBC2: For me to purchase functional food using red palm oil is easy. | 0.826 | | |
| 2016) | PBC3: The decision to purchase functional food using red palm oil is beyond my control. | 0.606 | | |
| | PBC4: Whether I purchase functional food using red palm oil is entirely up to me. | 0.676 | | |
| | AW4: It gives me confidence in buying functional food using red palm oil. | 0.873 | | |
| Purchase Intention | PI1: I have the intention to buy functional food using red palm oil soon. | 0.893 | 0.931 | 0.817 |
| (Moons *et al.*, 2018) | PI2: I will recommend buying functional food using red palm oil. | 0.905 | | |
| | PI3: I have the intention to buy functional food using red palm oil regularly. | 0.913 | | |

*Note: FI2 and FN3 were deleted due to low loading, [a] Composite Reliability (CR) [b] Average Variance Extracted (AVE)*

**Table 3.** Heterotrait – Monotrait (HTMT)

| | FI | FN | EC | HL | PV | PR | ATT | SN | PBC | AW | PI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **FI** | | | | | | | | | | | |
| **FN** | 0.366 | | | | | | | | | | |
| **EC** | 0.494 | 0.360 | | | | | | | | | |
| **HL** | 0.407 | 0.447 | 0.335 | | | | | | | | |
| **PV** | 0.365 | 0.416 | 0.348 | 0.468 | | | | | | | |
| **PR** | 0.324 | 0.340 | 0.248 | 0.432 | 0.421 | | | | | | |
| **ATT** | 0.361 | 0.392 | 0.323 | 0.436 | 0.553 | 0.306 | | | | | |
| **SN** | 0.323 | 0.339 | 0.246 | 0.441 | 0.450 | 0.400 | 0.606 | | | | |
| **PBC** | 0.468 | 0.381 | 0.421 | 0.465 | 0.485 | 0.325 | 0.550 | 0.543 | | | |
| **AW** | 0.444 | 0.442 | 0.381 | 0.506 | 0.549 | 0.375 | 0.605 | 0.512 | 0.555 | | |
| **PI** | 0.405 | 0.307 | 0.375 | 0.363 | 0.477 | 0.238 | 0.616 | 0.487 | 0.507 | 0.562 | |

Note: Food Involvement (FI), Food Neophobia (FN), and Environmental Concern (EC), Healthy Lifestyle (HL), Perceived Value (PV), Perceived Risk (PR), Attitude (ATT), Subjective Norm (SN), Perceived Behavioural Control (PBC)

**Table 4.** PLS result of coefficient and hypotheses testing

| Hypothesis | Relationships | Path Coefficients | T Values | P Values | Decision | $R^2$ | $Q^2$ | $F^2$ |
|---|---|---|---|---|---|---|---|---|
| Direct Effect | | | | | | | | |
| H1 | FI -> PI | 0.088 | 1.645* | 0.050 | Supported | 0.486 | 0.36 | 0.009 |
| H2 | FN -> PI | -0.046 | 0.871 | 0.192 | Not Supported | | | 0.029 |
| H3 | EC -> PI | 0.095 | 1.702** | 0.044 | Supported | | | 0.010 |
| H4 | HL -> PI | -0.022 | 0.443 | 0.329 | Not Supported | | | 0.001 |
| H5 | PV -> PI | 0.099 | 1.603* | 0.052 | Supported | | | 0.010 |
| H6 | PR -> PI | -0.070 | 1.702** | 0.044 | Supported | | | 0.006 |
| H7 | ATT -> PI | 0.312 | 4.661*** | 0.000 | Supported | | | 0.084 |
| H8 | SN -> PI | 0.099 | 1.632* | 0.051 | Supported | | | 0.010 |
| H9 | PBC -> PI | 0.085 | 1.313* | 0.095 | Supported | | | 0.007 |

*Note: *p<0.10, **p<0.05, ***p<0.01 (based on one-tailed test with 5000 bootstrapping)*

## 5. Discussion

The current study found that attitudes, subjective norms, and perceived behavioural control have a positive and significant relationship with the purchase intention of red palm oil as a functional food. This finding provides the support that the TPB model predicts purchase intention. In addition, food involvement, environmental concern, perceived value, and perceived risk significantly affect consumers' purchase intention of red palm oil as a functional food. The inclusion of these additional variables can support the extended TPB model. On another note, it has come to our attention that there is no relationship between food neophobia and a healthy lifestyle and the purchase intention of red palm oil as a functional food. Out of the total nine hypotheses, two were not supported (i.e., H2 and H4).

In this study, food involvement is found to have a positive and significant relationship with consumers' purchase intention of red palm oil as a functional food. Consumers who demonstrated a greater level of food involvement are more likely to have a stronger purchasing intention than those with a lower regard for red palm oil as a functional food. This finding is consistent with Farragher et al. (2016) who proposed that food involvement influences consumption. This finding could assist the marketers in drafting a marketing campaign aimed at increasing consumer engagement in functional foods, namely those containing red palm oil for healthy consumption.

In contrast to earlier findings, no significant evidence was detected between the relationship of food neophobia and consumer purchase intention of red palm oil as a functional food. Even though this result differs from earlier work by Mak et al. (2017) that neophobia negatively influences food consumption intention, they are consistent with those who confirmed an insignificant relationship (Caber et al., 2018; Moons et al., 2018). It is difficult to explain this result, but it might be related to the younger consumers in this study. Young consumers tend to have higher acceptance to sample new food and hence the possibility of having food neophobia among them is very minimal.

Environmental concern was found to positively influence consumers' purchase intention of red palm oil as a functional food. When consumers have a greater environmental concern, the stronger is the purchase intention for red palm oil as a functional food. This confirms previous findings in the literature by Imani et al. (2021) on the organic product. Marketers are suggested to promote the use of red palm oil as a functional food produced from sustainable oil palm plantations that could help in conserving forest areas. With this in mind, a consumer who is more environmentally conscious will demonstrate a stronger purchasing intention with red palm oil as a functional food option. It is worth noting that there is no relationship between a healthy lifestyle and consumer desire to purchase red palm oil as a functional food. It is often assumed that health-conscious consumers tend to purchase healthy food products. Nonetheless, although there is no effect, previous research by


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Küster-Boludaa and Vidal-Capilla (2017) found that a healthy lifestyle negatively influences the willingness to consume functional food.

In terms of perceived value, this variable positively influenced consumer purchase intention of red palm oil as a functional food. The finding was aligned with previous studies. The perceived value of palm oil (i.e., red palm oil) is useful for several purposes, from skincare to hair treatment, and the most essential benefit in preventing cardiovascular disease (Clemens et al., 2017). On the other hand, perceived risk negatively influenced consumer purchase intention of red palm oil as a functional food. The finding was consistent with a past study (Yang et al., 2015). Untrusted and uncertainty are two main factors affecting consumer choices of novel food, such as functional food containing red palm oil. Additionally, respondents in this study were highly educated (75.1% with bachelor's degrees) and aware of the risk of consuming novel food. It is often suggested that acceptance of novel food can be enhanced by nutrition knowledge (Alphonce et al., 2020). Therefore, marketers and government bodies should continuously promote functional food using red palm oil by advertising the benefits in traditional media and social media (Reaz et al., 2020).

As predicted, our study proved that attitude, subjective norm, and perceived behavioural control all had a positive and significant relationship with red palm oil purchasing intentions as a functional food. This finding demonstrated that TPB may explain consumer purchase intention. A favourable attitude positively affects consumer purchase intention. Our results shared some similarities with Imani et al. (2021), James et al. (2019), and Lim and Goh (2019). When red palm oil as a functional food is considered to be a healthier food choice, the consumer tends to have a favourable evaluation and this leads to higher purchase intention. Subjective norm positively affects consumer purchase intention of red palm oil as a functional food. When consumers perceived that their family members and friend encourage them to try out red palm oil, their purchase intention could get influenced. The result was consistent with past studies (Imani et al. 2021; Lim & Goh, 2019; Teng & Wang, 2015; Yangui et al. 2016). Lastly, there is a positive and significant relationship between perceived behavioural control and consumer purchase intention of red palm oil as a functional food. The consumer who feels confident and is capable of purchasing food such as red palm oil as a functional food will mostly lead to a stronger purchase intention. The result was aligned with Imani et al. (2021) and Yangui et al. (2016) findings.

## 6. Conclusion

In summary, this study presented several contributions. Firstly, this study adds to a growing body of literature on consumers' purchase intention of red palm oil as a functional food in the Malaysian context. Secondly, this study provided further evidence that TPB constructs are a robust model, and we confirmed its explanatory influence on purchase intention and an extended TPB model with the inclusion of additional variables provides a better explanatory interpretation of the purchase intention of red palm oil as a functional food. Nonetheless, we are aware that our study may have two limitations. The first is related to the cross-sectional design used in this study. It is not possible to examine the causal relationship between the variables. Moreover, this study measured purchase intention, not actual purchase behaviour. It is suggested that future studies could choose a longitudinal study that could observe the change in consumer purchase behaviour over an extended period. The second is the convenience sampling method which may have the potential for selection bias. Future studies could look into incorporating simple random sampling in the current context.

## Conflict of Interest

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

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# Comparative study of white LED light and dark condition in domestic refrigerator on reducing postharvest strawberries waste

TUANY GABRIELA HOFFMANN[1,*], SARAH FINARDI[1], JULIA TOMAZONI DE OLIVEIRA[1], EDUARDA MUELLER[1], SÁVIO LEANDRO BERTOLI[1], MURLIDHAR MEGHWAL[2] AND CAROLINA KREBS DE SOUZA[1]

[1] Department of Chemical Engineering, University of Blumenau, Blumenau, Brazil
[2] Department of Food Science and Technology, National Institute of Food Technology Entrepreneurship & Management Kundli, Haryana, India

* Corresponding author: tuanyhoffmann@gmail.com

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LED, strawberry, refrigeration, food preservation

Strawberry is one of the most consumed fruits in the world, and due to its perishability, there is a need for new preservation technologies capable of extending its shelf life. An alternative for the preservation of short shelf life fruits is refrigeration associated with LED lights. In this context, the present study evaluated the effect of white LED light in strawberry preservation at the postharvest condition. Strawberry samples were stored in a perforated package under refrigeration (5 °C), in the presence and the absence of a white LED light. Samples were stored for seven days, and analysis was performed on days 0, 2, 4, and 7. Strawberry samples were analysed according to the physical, nutritional, and sensorial indexes. The results showed that white LED light incidence on strawberries results in higher transpiration rates (1030.3 ± 78.2 mg $kg^{-1}$ $h^{-1}$), ascorbic acid degradation (85%), and instability in the total polyphenols content. The sensorial evaluation showed no influence from the presence or absence of white LED light in strawberry preservation of the visual quality. In brief, the results encourage the market to develop new refrigeration technologies, emphasizing that the use of white LED light, during the postharvest stage, can reduce strawberry preservation.

## 1. Introduction

Strawberry is a fruit with sensory characteristics that make it appealing to consumers, such as its bright red colour, distinct aroma, soft texture, and slightly acidic flavour. According to Musa et al. (2015), strawberry is a potential source of bioactive compounds, such as vitamin C and phenolic compounds. However, this non-climacteric fruit has a delicate skin that is prone to surface crushing (Zhang *et al.,* 2018), and has a short shelf life (Lan *et al.,* 2019; Finardi *et al.,* 2022).

As a result of its high susceptibility to mechanical injury, water loss, microbial and physiological deterioration, and high respiration rate (Nguyen *et al.,* 2020), postharvest handling and storage of this fruit is a complex matter. Hence, due to the high perishability and physiological activity of strawberries during the postharvest period, fast cooling at low temperatures is the most appropriate method for controlling strawberry senescence (Han *et al.,* 2004; Hoffmann *et al.,* 2021a).

Despite the high price, there is an increasing demand for fresh strawberries. For this reason, alternatives to

increasing the distribution ratio and extending strawberry shelf life are of interest (Almenar *et al.,* 2006). Besides storage at optimal temperature for preservation, the combination of low temperature with innovative technologies, such as ozonation (Soares *et al.,* 2018), food coating (Angioletti *et al.,* 2020), intelligent and active packaging (Hoffmann *et al.,* 2019, Hoffmann *et al.,* 2022), and UV and LED lights application has been discussed in the literature (Finardi *et al.,* 2021).

Light-emitting diodes (LEDs) are lighting devices with high photoelectric efficiency, low thermal output, compactness, and portability and are easily integrated into electronic systems (D'Souza *et al.,* 2015). This solid-state lighting can be applied to postharvest preservation, as it can affect the secondary metabolite of plants (Kasim & Kasim, 2017). The role of LED light is to delay the senescence of perishable fruits and vegetables, allowing them to be modified in terms of their nutritional content, fruit ripening rate, and prevention of fungal infections, which reduces food spoilage (D'Souza *et al.,* 2017).

Jiang et al. (2019) claimed that the use of light-emitting diodes has some advantages when applied to extend the shelf life of harvested fruits and vegetables. LED used in postharvest storage can delay senescence, provide nutritional enhancement, and reduce microbiological deterioration. Chong et al. (2022) also observed the contribution of LED light to the inactivation of microorganisms (*Rhizopus stolonifer* and *Botrytis cinerea*) and the physicochemical properties of strawberries. On the other hand, some negative effects were also observed. According to Hasperue et al. (2016), the use of LED light in broccoli preservation caused a higher weight loss, which resulted from the opening of the stomata when exposed to LED.

In strawberries preservation, it was observed that the long exposure to LED light caused an increase in the transpiration rate (Duarte-Molina *et al.,* 2016). In addition, Xu et al. (2014) evaluated the application of blue LED light in strawberries and the results evidenced the accelerated ripening by the increase in respiration and ethylene production. However, the use of blue, red, and green LED improved anthocyanin content in strawberries, when compared with the storage under dark conditions. The vitamin C content was preserved under blue and green LED lights and total phenolics production was stimulated under blue LED light (Kim *et al.,* 2011, D'Souza *et al.,* 2015).

In light of these considerations, this research objective is to investigate the effects of white LED incidence in strawberry preservation during postharvest storage. For this reason, the strawberries were submitted to different storage conditions (presence and absence of white LED), under refrigeration.

## 2. Materials and methods

### 2.1 Postharvest treatment and storage conditions

Strawberry samples were harvested from a hydroponic cultivation system in Indaial, Santa Catarina (Brazil). Fresh fruit sample selection was based on their uniform size (length/width of about 0.9-1.2), weight (15-20 g), colour (uniform colour all over the strawberry surface and between the samples), and maturity (30 days), as well as the absence of mechanical damage and diseases. Once harvested, samples were immediately transported, under refrigerated conditions (cooled box), within 1 hour, to the Laboratory of Food Preservation & Innovation (University of Blumenau).

Before storage, strawberry samples were washed under running water and the remaining surface water was removed with absorbent paper by applying gentle pressure. Then, the samples were packaged in polyethylene terephthalate material (15 cm x 13 cm x 5 cm), with 3 perforations of 1.5 cm of diameter at the cover. Each package included 4 samples of strawberries.

The samples were stored under dark and white LED light conditions, with 2 lx and 180 lx of luminosity, respectively. The white LED light was adjusted at 25 cm of distance from food samples and the white LED light power was 7.2W. In both conditions, the presence and the absence of light, were evaluated in strawberry preservation, for 7 days at 5 °C, in BOD (Biochemical Oxygen Demand) chamber, and samples were analysed on days 0, 2, 4, and 7. Physical, nutritional, and sensorial indexes were collected in order to validate the effects of white LED light in strawberry preservation. For this reason, mass variation, transpiration rate, total polyphenols, ascorbic acid (AA), and sensorial analyses were conducted.

### 2.2 Physical index: mass variation and transpiration rate

Strawberry mass variation was determined based on each sample weight, over time. Mass variation (MV) was calculated from the initial ($M_i$, immediately after arrival at the laboratory) and final mass ($M_f$), as shown in Equation 1. The MV results were expressed as a percentage of mass loss/variation according to the fresh mass.

$$MV\ (\%) = \left(\frac{M_i - M_f}{M_i}\right) 100 \quad (1)$$

In addition, the strawberry transpiration rate (TR) was calculated per unit of initial mass and time (t), according to Equation 2 (Hoffmann *et al.,* 2021b).

$$TR\ \left(\frac{mg}{kg\ h}\right) = \left(\frac{M_i - M_f}{M_i \times \Delta t}\right) \quad (2)$$

### 2.3 Nutritional index: ascorbic acid and total polyphenols

Ascorbic acid (AA) content was measured using 2,6-dichloroindophenol, according to AOAC (2005). Strawberry samples (10 g) were grounded in a commercial processor (NPRO, Arno), for 3 min. The AA content was extracted from the ground material with oxalic acid 1%, for 15 min under dark conditions. Subsequently, the filtered extraction solution was obtained through a paper filter (C41, Unifil). Three aliquots of the filtrate were titrated with 2,6-dichloroindophenol and the results were expressed in mg of ascorbic acid 100 $g^{-1}$ of fresh weight (FW).

Total polyphenols content was determined using the Folin Ciocalteau method (Nguyen *et al.,* 2020), where the results were expressed in mg of gallic acid 100 $g^{-1}$ of fresh weight (FW). Briefly, strawberry samples (10g) were macerated and mixed with 20 mL of ethanol 96%. The solution was centrifuged (HERMLE, Z300K) at 4°C, for 10 min. The supernatant was collected and reacted with Folin Ciocalteu reagent and sodium carbonate 20% (w/v). The mixture was measured at the absorbance of 765 nm (UV-1800, SHIMADZU) and compared to the standard curve, which was developed using a standard solution of gallic acid.

### 2.4 Sensorial index: strawberry visual quality

The visual quality characteristic of strawberries was evaluated throughout the storage period by a sensory panel of five trained judges. Sensorial evaluations were carried out immediately after removing the strawberries from storage (5 °C), in an individual sensory booth, with control of the lighting, temperature, and the absence of noise (Meilgaard *et al.,* 2016). A nine-point hedonic scale, from excellent (9) to extremely poor (1), was used to evaluate the visual quality. This attribute was analysed considering food appearance, related to freshness, colour change, wilting, decay, and damage. A score of 6 was considered the shelf-life limit for strawberries. The execution of this project, which contemplates the participation of human beings, was approved by the Ethics Committee on Research with Human Beings at the University of Blumenau (CAAE: 48613415.1.0000.5370).

### 2.5 Statistical analysis

Data were subject to Tukey's test, at a 5% level ($p < 0.05$) of significance, in Statistica software 7.0 version (Box *et al.,* 2005). All analyses were performed in triplicate and the results are reported as the mean ± standard deviation.

## 3. Results

### 3.1. Mass variation

Figure 1 presents the mass variation results for strawberries stored under white LED light and in the dark. Strawberries lost weight at rates of 519.9 ± 76.4 mg $kg^{-1}$ $h^{-1}$ (under dark) and 1030.3 ± 78.2 mg $kg^{-1}$ $h^{-1}$ (in white LED light) in storage conditions, after 7 days. The results of mass variation showed that strawberries, submitted to white LED light, lost 19% of their weight, while strawberries in the dark, only 8% at the end of storage.

### 3.2. Ascorbic acid and total polyphenols

The lack of stability in ascorbic acid (AA) content resulted in a significant decrease ($p < 0.05$) in both storage conditions, with white LED light presenting


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higher reductions (85%) than storage in the dark (69%). Figure 2(a) presents the ascorbic acid content in strawberries during refrigerated storage.

AA degradation was modelled by first-order kinetics since the natural logarithm of the ratio between AA and initial AA (AA0) against time is well described by a straight line, as presented in Figure 2(b). Lines for each ascorbic acid degradation, under dark and white LED light, were LN(AA/AA0)=-0.1484t, R2=0.8927, and LN(AA/AA0)=-0.2437t, R2=0.9314, respectively. Strawberry stored under white LED light degraded 1.64 times faster than strawberry stored in the dark.
The total polyphenols results are presented in Table 1. The results showed that both storage conditions did not negatively influence the total polyphenols content, where an increase was reported.

### 3.3 Sensorial analysis

Figure 3 presents images of strawberries under the white LED light (a) and in dark (b). Strawberry images reveal that, after the 4th day of storage, microbial (mould) proliferation became more intense and visible. In addition, drip loss is observed at the bottom of the package on the last day of storage.
Strawberry visual quality showed great results on the first day (after harvest), with a small reduction at the beginning of storage (2nd day), as presented in Figure 4. The main reason for this reduction, in visual quality, is the presence of small bruises on the strawberry surface and loss of luminosity in the samples due to mass loss. A more intense reduction, in visual quality, was registered after the 4th day, due to the presence of microbial proliferation. However, no significant difference ($p>0.05$) was observed in the preservation of the strawberry, when comparing the different conditions (white LED light and in the dark).

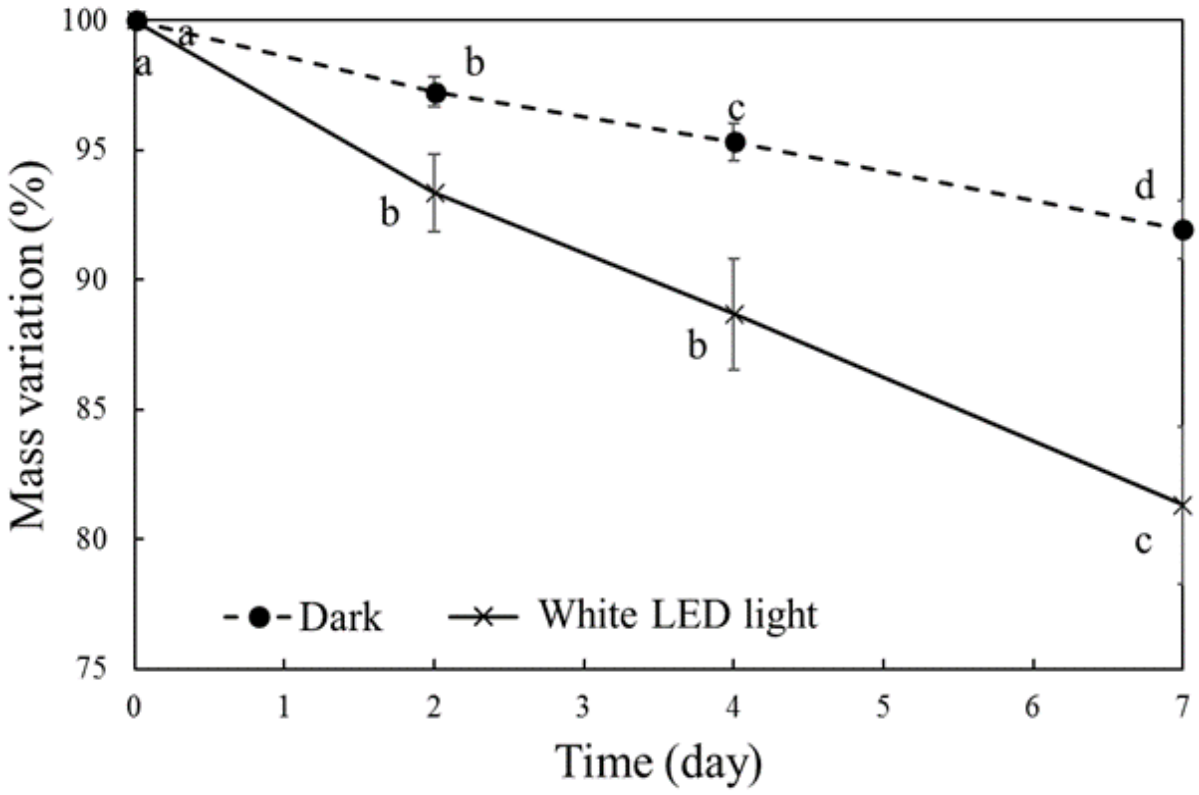


**Figure 1.** Strawberry mass variation under white LED light (×) and in the dark (•). Means ± SD (n = 3) with different letters are significantly different at 5% level, between white LED light and dark condition.

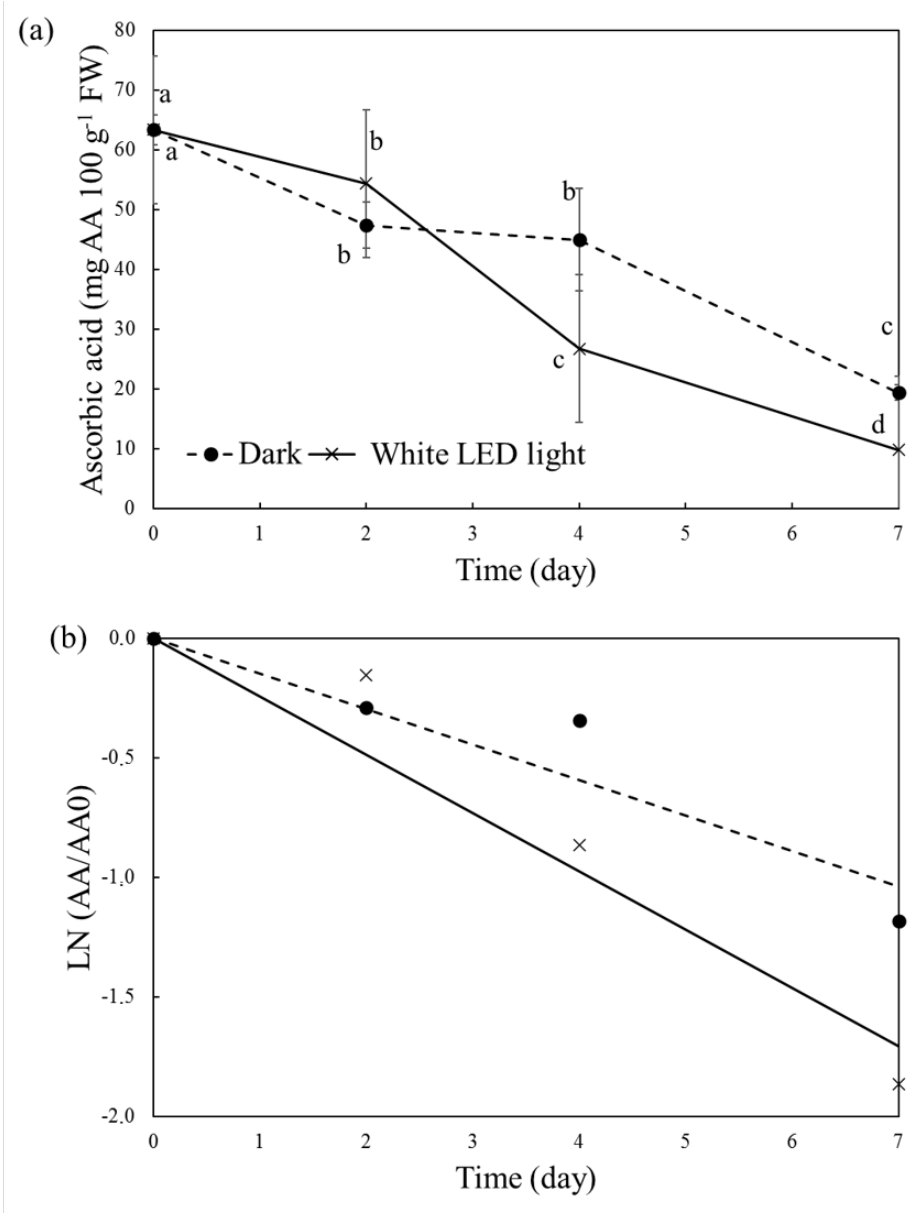


**Figure 2.** Strawberry ascorbic acid (AA) content in (•) dark and (×) white LED light (a), and AA degradation (b) during the storage time. Means ± SD (n = 3) with different letters are significantly different at 5% level, between white LED light and dark condition. AAO is the ascorbic acid at the initial of storage.

## 4. Discussion

Mass variation is mainly associated with respiration heat and evaporative cooling from the food surface, in response to transpiration. Both processes, transpiration, and respiration play an important role in water maintenance in the postharvest quality of strawberries (Hoffmann *et al.*, 2021b). The higher transpiration rate observed in strawberries stored under the white LED light was circa 2 times higher than the one observed in the absence of light, consequently resulting in the higher mass loss (mainly associated with the loss of water). Duarte-Molina et al. (2016), also observed higher mass loss in strawberries treated with a longer exposition of light and related this result to the tissue injury caused in strawberry samples due to light incidence. Photorespiration can additionally play an important role in strawberry transpiration under the white LED light once the achenes present in the strawberry, even after postharvest, have photosyn-


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**Table 1.** Total polyphenols under the presence and absence of white LED light. (Means ± SD (n = 3), with different letters, are significantly different between white LED light and dark condition, at 5% level)

| Total polyphenols (mg gallic acid 100g$^{-1}$ FW) | | |
|---|---|---|
| Day | Dark | White LED |
| 0 | 1.8±0.1$^{a}$ | 1.8±0.1$^{ab}$ |
| 2 | 1.8±0.2$^{a}$ | 1.7±0.1$^{a}$ |
| 4 | 1.9±0.0$^{a}$ | 1.9±0.1$^{ab}$ |
| 7 | 2.0±0.0$^{a}$ | 1.9±0.1$^{b}$ |

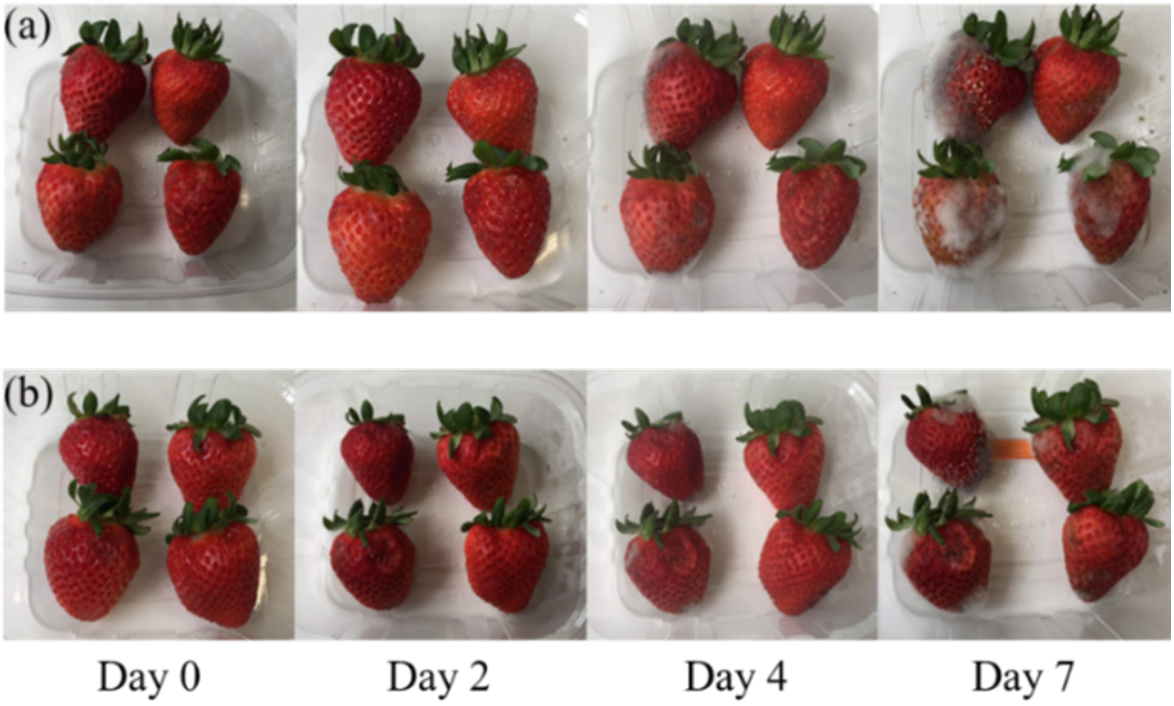


**Figure 3.** Visual quality of strawberry under white LED light (a) and in the dark (b), during the 7 days refrigerated storage.

thetic capacity due to chlorophyll incomplete decomposition, which leads to photorespiration (Meyerhoff and Pfündel, 2008). This physiological process has a direct effect on the metabolism and transpiration from fresh food produce, such as strawberries. According to Sastry and Buffington (1983), water removal from fresh food produce is assisted by evaporative heat due to the respiration mechanism, in which metabolism provides heat. For this reason, several studies recommend reducing the respiration rate to preserve fresh food produce (Chaomuang *et al.*, 2019, Hoffmann *et al.*, 2021a).

In accordance with mass loss, the ascorbic acid (AA) also presented a superior level of degradation under white LED light, when compared to dark condition, with approximately 16% higher AA degradation, after 7 days of storage. Xu et al. (2014), in a study with strawberries stored under blue LED light, obtained a higher level of ascorbic acid after 4 days, with ap-

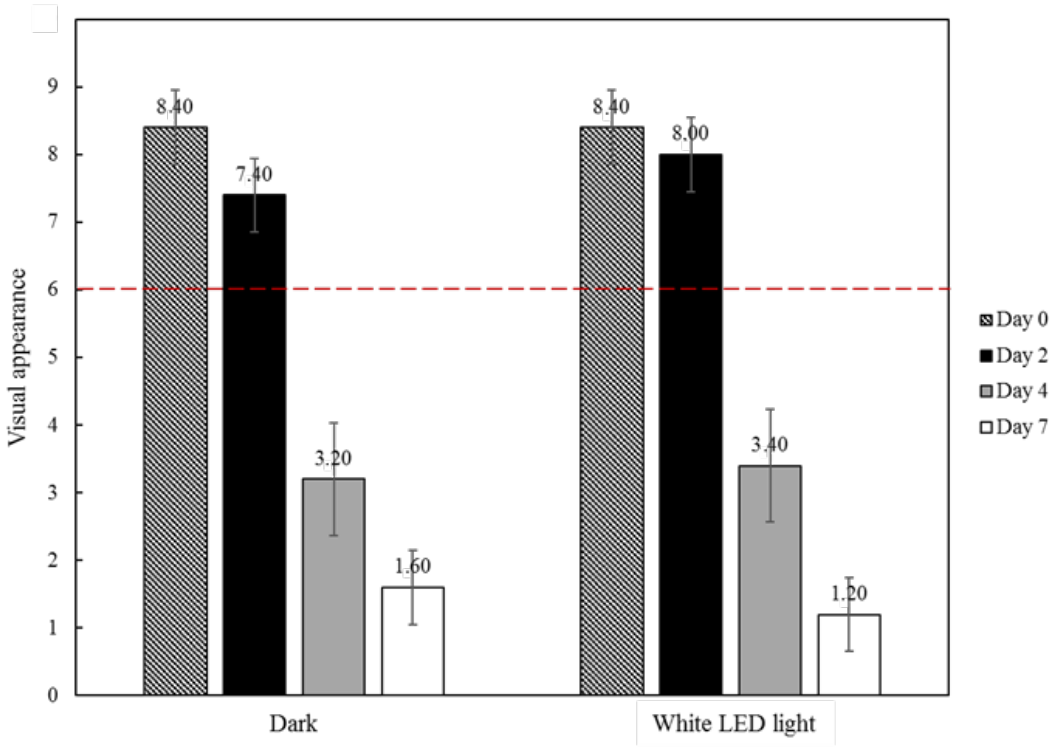


**Figure 4.** Visual quality white LED light and in the dark condition, in strawberry preservation under refrigeration, during the 7 days storage. (---) represents visual acceptance limit.

proximately 1.25 mg $g^{-1}$ FW, at the end of 12 days of storage. On the other hand, the AA content in spinach, exposed to white LED light, showed 32% higher degradation than the samples stored in the dark, after 16 days of storage (Toledo *et al.,* 2003). The AA is an unstable vitamin present in strawberries. According to Klein (1987), some of the factors that have an important influence on AA content in food are temperature, pH, and light incidence. The reduction of ascorbic acid in strawberries can also be related to the mass loss (higher under white LED light) since the water movement, from the inside to the surroundings of the strawberries, carries other substances therein, such as vitamins, pigments (Ramallo and Albani, 2004, Agüero *et al.,* 2011).

The increase in total polyphenols content in strawberries can be associated with the mass loss since the water reduction from the samples resulted in an increase in polyphenols concentration. This correlation was presented by Agüero et al. (2011), who demonstrated that the quantification of the nutritional content in lettuce, when dealing with dried weight basis, reduces during food storage. In contrast to the fresh weight basis, which does not consider the water reduction from food and, for this reason, the results from substances are presented in higher levels. Despite the total polyphenolic compounds presenting similar results in both conditions evaluated in this study (white LED light and dark condition), the mass loss was significantly higher in the strawberries stored under white LED light, which may have provided a higher concentration in total polyphenols when results were presented in fresh weight basis. This observation led to the analysis that the total polyphenols under white LED light could be more degraded in this condition.

The visual quality presented no significant difference, in the strawberry preservation, under the presence and absence of white LED light, as shown by the sensorial analysis. The main factor that controlled the visual quality in this study was microbial proliferation because when moulds were visually present, after the 4th day, the sensorial scores dropped significantly. Both conditions, white LED light and dark condition, provided microbial proliferation, on a visual scale, at the same period, which can suggest that the different conditions did not influence this result. However, a


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deeper study on microbial quantification is needed. In addition to microbial proliferation, the influence of tissue damage and bruising at the strawberry surface can also decrease sensorial scores.

## 5. Conclusion

The white LED light, when applied in the postharvest preservation of strawberries, had presented a negative effect, which can be mainly associated with photorespiration, caused by light incidence. This physiological process, stimulated by light, accelerated the mass loss by increasing the transpiration rate and, consequently, provided higher degradation of the ascorbic acid and total polyphenols content present in the strawberries. The sensorial scores, evaluated according to the visual quality, did not present influence from the presence or the absence of white LED light, while the microbial proliferation played an important role in the sensory evaluation, by reducing its visual quality value. In summary, the effects of the white LED light observed in strawberry indicates that, during the postharvest stage, this fruit storage should be conducted in the absence of light (white LED light) to preserve its organoleptic properties for longer.

## Conflict of interest

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

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# The effect of transglutaminase on physicochemical, microstructural, and organoleptic properties of low-fat Karish cheese

**ALZAHRAA DARWISH**[1*]

[1]Department of Dairy Science, University of Assiut, Assiut, Egypt.

* Corresponding author: zahraa@aun.edu.eg

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karish cheese;
transglutaminase;
microstructural;
organoleptic properties;
milk proteins

Karish cheese is considered to be one of the most traditional Egyptian cheeses. It is manufactured from low-fat milk. It can be a key part of a healthy diet, especially for the elderly and those suffering from obesity-related illnesses. Low-fat cheeses, such as karish, have a crumbly texture, which is a major issue for cheesemakers. This research aimed to improve the texture of karish cheese using transglutaminase (TGase), and to study the effects on cheese's physical, microstructural, and organoleptic properties at different TGase levels of 1.0, 1.5, and 2.0 U $g^{-1}$ protein. TGase increased the structure of karish cheese at a rate of 1.5–2.0 U $g^{-1}$ protein, compared to the control sample. Scanning electron microscopy images showed that the protein matrices in karish cheese samples that had been treated with TGase were relatively more compact than those in the untreated sample. Proteins in karish cheese samples treated with TGase showed crosslinking in SDS-PAGE scans. Casein fractions corresponding to bands became less intense as the concentration of TGase increased. To summarise, TGase improved the characteristics of karish cheese at the rate of 1.5–2.0 U $g^{-1}$ protein TGase, and this structural modification is recommended for such traditional cheese in order to fulfill customer demand.

## 1. Introduction

Karish cheese is the most popular low-fat soft cheese consumed in Egypt. The coagulating agent of the cheese is a mixed culture of lactic acid bacteria (Delacroix-Buchet et al., 2005). Karish, also known as kariesh or kareish cheese, is a common lactic cheese produced from fresh skimmed milk. It includes the bulk of the components present in skim milk. Defatted milk such as Laban Rayeb, Laban Khad, Laban Zeer, or mechanically skimmed milk are also used in the production of karish cheese (Laban Farz) (S.A., 2008). As a highly demanded low-fat cheese and a healthier dietary option for many in Egypt and other Arab countries (Allam et al., 2017; Topcu et al., 2020), low-fat cheese is still the best choice for obese and diabetic patients' diets (Sayadi et al., 2013). However, low-fat content in cheese results in some structural problems, such as a hard and rubbery texture, and low meltability and stretchability. Furthermore, cheese flavour, colour, and mouthfeel are affected (Pereira et al., 2009).

The competitive dairy industry is trying to improve the quality and usefulness of low-fat dairy products for improved customer acceptance (Lauber et al., 2000; Şanlı et al., 2011). The modification of milk proteins by enzymes to create a cheese with improved output and quality features has been used in the dairy

industry for a long time (Danesh et al., 2018; Soltani et al., 2022; Topcu et al., 2020).

Transglutaminase (TGase) is currently widely used in the food industry because it enhances the functionality, solubility, and emulsification of products by forming links within the protein molecules (Martins et al., 2014). TGase amplifies the textural properties of protein-gel-based dairy products (Monsalve-Atencio et al., 2022; Zhang et al., 2012). TGase is a member of the transferase family, protein-glutamine: amine-glutamyl transferase (TGase, EC 2.3.2.13) (Kieliszek & Misiewicz, 2014; Wang et al., 2018). The crosslinking of milk proteins with TGase is one of the most recent methods for enhancing the biofunctional properties of low-fat cheese products.

TGase has been shown to primarily catalyze protein crosslinking on α-lactalbumin and β-lactoglobulin in whey protein studies. This is primarily because the TGase enzyme can enhance the rheological and physical characteristics of milk-based acid gels by producing intra- and intermolecular ionic crosslinks between two amino acid residues in the milk proteins αs1, αs2, β and κ-caseins, and whey protein (El-Kiyat et al., 2021; Gharibzahedi et al., 2018; Rodriguez-Nogales, 2006). Additionally, TGase is a crosslinking enzyme that can catalyze α -lactoglobulin, β-lactoalbumin, and even caseinomacropeptide (Tolkach & Kulozik, 2005) crosslinking in cheese whey by producing intramolecular and intermolecular ε-(γ-glutamyl) lysine crosslinks, resulting in a high-molecular-weight polymer. However, without the presence of a mediator to enhance enzyme catalysis, TGase may catalyse protein crosslinking.

The protein chain of α-lactalbumin consists of 8 glutamine residues and 12 lysine residues, whereas β-lactoglobulin contains 16 glutamine residues and 15 lysine residues (Gauche et al., 2008). The reactions of catalyzed TGase are as follows:

R-Glu-CO-NH2 + H2N- R′ → R-Glu-CO-NH R′ + NH3

R-Glu-CO-NH2 + H2N-Lys- R′ →R-Glu-CO-NH-Lys-R′ + NH3

R-Glu-CO-NH2 + H2O → R-Glu-CO-OH + NH3 (Rachel & Pelletier, 2013).

TGase is utilised to improvise a range of activities, including coagulation and antibacterial immune responses (Kashiwagi et al., 2002). The present goals are to augment the functional qualities of low-fat cheese to meet the demands of cheesemakers and customers, to optimize structure characteristics by developing manufacturing strategies that used TGase, and to identify the optimal concentration of TGase to achieve the goal.

## 2. Materials and Methods

### 2.1. Materials

Low fat pasteurized cow and buffalo milk was used in the production of karish cheese samples. The fat and total solid contents of the pasteurized milk were 0.1% and 12.8%, respectively. Ajinomoto Co. provided the TGase, while Ajinomoto Co., Inc., France provided the food enzyme preparation. The TGase activity was reported to be 120 U g1protein (data supplied by the industry from Merck Chemicals Ltd.). All provided chemicals were of analytical grade (Darmstadt, Germany).

### 2.2. Karish Cheese Manufacturing

Karish cheese was manufactured according to the method of Ezzel-Din (1978). Fresh skimmed cow and buffalo milk (1:1) (1 g fat/100 mL milk) was heat-treated at 85 °C/15 s and left to cool to 40 °C in ice water for 10 minutes. The milk used for karish cheese production was divided into four portions. The first portion was the control karish cheese (C) without TGase addition. The three other portions were treated with 1.0, 1.5, and 2 U $g^{-}1$ protein TGase. The active yoghurt starter culture of Streptococcus thermophilus and Lactobacillus delbrueckii subsp. Bulgaricus (1:1) was obtained from CHR Hansen Lab (Denmark) and was added at the rate of 1.5% of the weight of skimmed milk to complete coagulation. The samples were then treated with 0.02 percent calcium chloride and incubated at 40 °C. After coagulation, 2.5% salt was added to the curd, which was ladled onto mats; the cheese curd was then moved to the refrigerator overnight at 5 ± 2 °C. Cheese samples were taken for chemical and organoleptic measurements after 24 h.

### 2.3. Proximate Analysis

The fat, protein, and titratable acidity of the samples were determined using AOAC (2000) methods. The nitrogen content (N) of the samples was estimated using the method described by AOAC (1990), and crude protein was calculated as N × 6.25 (Imran et al., 2008). The ash content was evaluated by dry ashing the samples in a muffle furnace at 550 °C for 6 hours. Before being placed inside the muffle furnace, samples were dried in a 105 °C oven.

### 2.4. Scanning Electron Microscopy (SEM)

Two or three 0.5 to 1 cm samples were collected from the cheese mats and fixed in 5 °C cold buffered gluteraldehyde for two days. Samples were then washed with cacodylate buffer three times for 15 minutes each and postfixed in 1% osmium tetroxide for 2 hours. Next, the samples were again washed in cacodylate buffer three times for 15 minutes each and then dehydrated using an ascending series of ethanol of 30%, 50%, 70%, and 90% for 2 hours each, 100% for two days, and then amyl acetate for two days. Critical-point drying was applied to the samples using liquid carbon dioxide. Each sample was fixed onto metallic blocks using silver paint. By using a golden sputter-coating apparatus, samples were evenly gold-coated to a thickness of 15 nm. Samples were photographed and examined using a JEOL JSM 5400 LV scanning electron microscope 15–25.kv (Bozzola & Russell, 1999).

### 2.5. Sodium Dodecyl Sulfate–Polyacrylamide Gel Electrophoresis (SDS-PAGE)

SDS-PAGE of karish cheese samples was performed as described by Fling and Gregerson (1986) using a stacking gel of 4% (wt/vol) and a resolving gel of 12.5% (wt/vol). Electrophoresis was carried out on 9.4 × 8 × 1 mm slabs utilizing a vertical slab unit (Gel electrophoresis equipment, biometra Eco_Mini) and an electrophoresis power supply. Proteins from karish cheese were isolated using SDS electrophoresis, as described by Kalit et al. (2005) according to Laemmli, 1970. A total of 1.2 g of previously ground cheese was extracted for 30 minutes at 40 °C with steady shaking in 15 mL of buffer (0.5 M Tris-HCl, pH 6.8, 2% (wt/vol) SDS, 7% (vol/vol) glycerol, 5% (vol/vol) 2-mercaptoethanol). The obtained suspension was centrifuged at 2.600 g for 15 minutes. The clear solution under the top layer was then carefully removed and diluted with a sample buffer (0.5 M Tris-HCl, pH 6.8, 2% (wt/vol) SDS, 7% (vol/vol) glycerol, 4.3 vol/vol) 2-mercaptoethanol, 0.0025% (wt/vol) bromophenol blue). The ratio of extract to sample buffer was 1:3. Samples that had been diluted and frozen were used. Samples were heated for 5 minutes at 95 °C and then cooled to room temperature before electrophoresis. Each well was filled with 25 µL of the SDS-PAGE samples. To complete the gels, they were operated at 120 volts per gel for 2 hours. Gels were fixed and stained for 3 hours with 0.1% (wt/vol) Coomassie Blue R-250 (dissolved in 10% (vol/vol) glacial acetic acid) and 50% (vol/vol) methanol, and then unstained with 10% glacial acetic acid and 50% (vol/vol) methanol. Data from Pesic et al. (2012) were utilized for casein fraction measurements as well as molecular weight. SDS-PAGE was performed twice.

### 2.6. Organoleptic Properties

Twenty-one panellists (11 male and 10 female panellists, aged between 30 to 52 years) having expertise with white cheese and regular use of its descriptive terminology took part. Cheese samples were rated on colour and appearance (15 points), flavour (50 points), body and texture (35 points), and overall acceptability (100 points) according to Clark et al. (2009). Members of the panel were also instructed to report any flaws or disagreeable flavours.

### 2.7. Statistical Analysis

To assess the statistically significant differences in the experimental data, analysis of variance (ANOVA) was done using IBM SPSS statistics version 21 software. Results were deemed statistically significant when $p \leq 0.05$. Values for the mean ± standard deviation are also presented.

## 3. Results and Discussion

### 3.1. Proximate Analysis

Table. 1 shows the chemical composition of the karish cheese samples. Protein content increased significantly ($p \leq 0.05$) in karish cheese samples at TGase levels of 1.5 and 2.0 U $g^{-1}$ protein. These results agree with those of García-Gómez et al. (2019), who hypothesised that protein growth might be due to covalent bonding created between milk protein molecules (glutamine and lysine). TGase may also bind casein micelles to-


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gether by forming crosslinks between different types of casein. β-lactoglobulin and α-lactalbumin are considered to be excellent TGase substrates (Razeghi & Yazdanpanah, 2020). There were no significant variations in ash, acidity, and fat values ($p \geq 0.05$) among the control and TGase-treated karish cheese samples. These findings corresponds with those of Aloğlu and Öner (2013), and Farnsworth et al. (2006).

### 3.2. Microstructural Analysis

TGase-treated and control karish cheese samples were examined with an SEM microscope, and micrographs (1000×) of these samples are shown in Figure 1. The control had an unstructured matrix, with certain areas being well-structured due to the development of thin strands arranged in a way that favoured the production of relatively small pores, while other areas in the control karish cheese had a high degree of compaction and large pores. In contrast, after treating milk with 1, 1.5, and 2 U $g^{-1}$ protein TGase, the protein network significantly changed, displaying a homogeneous and, at a glance, fluffy network with abundant thick strands of protein aggregates that interacted with one another, as well as visible changes in the porosity pattern. The SEM microstructures are shown in Figure 1. The greater strength of karish cheese gels produced from crosslinked milk with increasing TGase in the treated samples with 1.5 and 2 U $g^{-1}$ protein TGase was analyzed, showing a well-organized protein network with smaller pores in the treated product. This more stable structure was the result of the reduced permeability of the gel formed by the action of TGase. These results agree with those of Cadavid et al. (2020), who studied the effect of TGase treatment on the functional properties of semi-skimmed cow milk cheese through its crosslinking activity, where TGase appeared to be able to enhance the cheese microstructure by modifying the protein aggregation pattern.

### 3.3. SDS-PAGE

The electrophoretic separation of karish cheese samples in polyacrylamide gel was performed to confirm changes in the milk proteins in karish cheese produced with the addition of TGase. The SDS-PAGE examination of karish cheese samples treated with TGase indicated the crosslinking of proteins (Figure 2). These results were similar to those of Ozer et al. (2007). Figure 2 shows that as the concentration of TGase increased, the bands corresponding to casein fractions became less intense. According to the results of Cadavid et al. (2020), the increase in the molecular mass of the casein fractions might be attributed to a crosslinking process elicited by the presence of TGase. The number of monomeric whey proteins (α-lactalbumin and β-lactoglobulin) in control karish cheese samples was compared to those in TGase-treated samples. With the addition of TGase, the number of monomeric whey proteins reduced, and several new compounds were formed that did not join the stacking gel due to their molecular weight. The partial deamidation of glutamine and ε-amino groups by TGase treatment reduced the surface hydrophobicity of protein molecules and enhanced electrostatic repulsion. The consequent change in the isoelectric point of whey protein predicted a change in the solution consistency index (Gauche et al., 2008).

### 3.4. Organoleptic Properties

Enzymes are employed to improve the overall quality of foods (Fernandes, 2010) in a variety of food and beverage industries, including cheese manufacturing

**Table 1.** Mean values[a] for chemical composition of control and TGase-treated (1.0, 1.5, and 2 U $g^{-1}$ protein) karish cheese samples.

| Samples | Ash% | Protein% | Fat% | acidity% |
|---|---|---|---|---|
| Control | 4.50±0.07 [a] | 16.2±0.04 [b] | 0.23±0.05 [a] | 1.92±0.06 [a] |
| 1.0 U | 4.38±0.05 [a] | 16.5±0.07 [b] | 0.25±0.03 [a] | 2.05±0.02 [a] |
| 1.5U | 4.75±0.12 [a] | 17.1±0.05 [a] | 0.26±0.05 [a] | 1.95±0.02 [a] |
| 2.0U | 4.54±0.05[a] | 17.3±0.10 [a] | 0.27±0.02 [a] | 2.13±0.03 [a] |

[a,b,c] Values in the same columns having different superscripts were significantly different ($p \leq 0.05$).
[a]Mean values ± standard deviations.

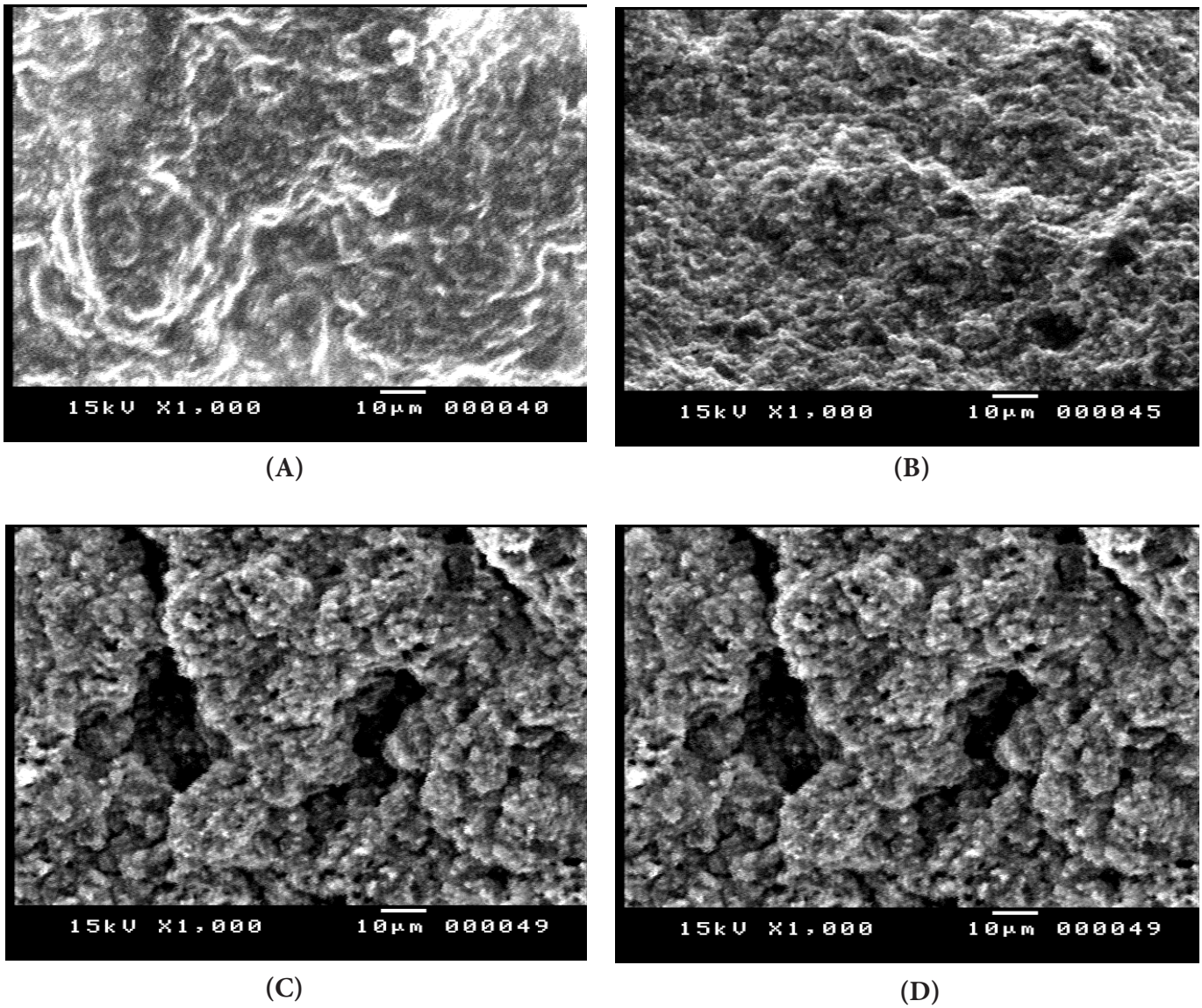


**Figure 1.** Scanning electron micrographs (1000×) of karish cheese samples: (A) control (without TGase treatment), (B) 1.0 U, (C) 1.5 U, and (D) 2 U g–1 protein TGase-treated samples.

(Gurung et al., 2013). The results of the organoleptic properties of the control and TGase-treated karish cheese samples are shown in (Table 2). The results revealed that there were no significant differences ($p \geq 0.05$) among karish cheese samples in colour and appearance and flavour; these results correspond with those of Hovjecki et al. (2021). Vice versa, data on the organoleptic properties revealed that there were significant differences ($p \leq 0.05$) among karish cheese samples in body and texture; these results correspond with those of Darwish et al. (2019). The (2.0 U) TGase-treated karish cheese sample had the highest body and texture of (34.9) whereas the control karish cheese sample had the lowest overall acceptability of (28.1). Furthermore, when the general acceptability of the sensory qualities was examined, there was a significant difference ($p \leq 0.05$) between the (1.5 U and 2.0 U) TGase treated karish cheese samples and control and (1 U). The overall acceptance of the control karish cheese sample was (87.1), whereas the 2.0 U TGase-treated karish cheese sample had the highest overall acceptability of (97.3). These results agree with those of Kumazawa and Miwa (2009), who discovered that using transglutaminase in cheese manufacturing had a substantial influence on texture and hardness. However, there was no significant difference in the colour, appearance, and flavour of karish cheese that was treated with TGase and the control samples; these findings coincide with those of Şanlı et al. (2011). Lastly, the addition of TGase to karish cheese


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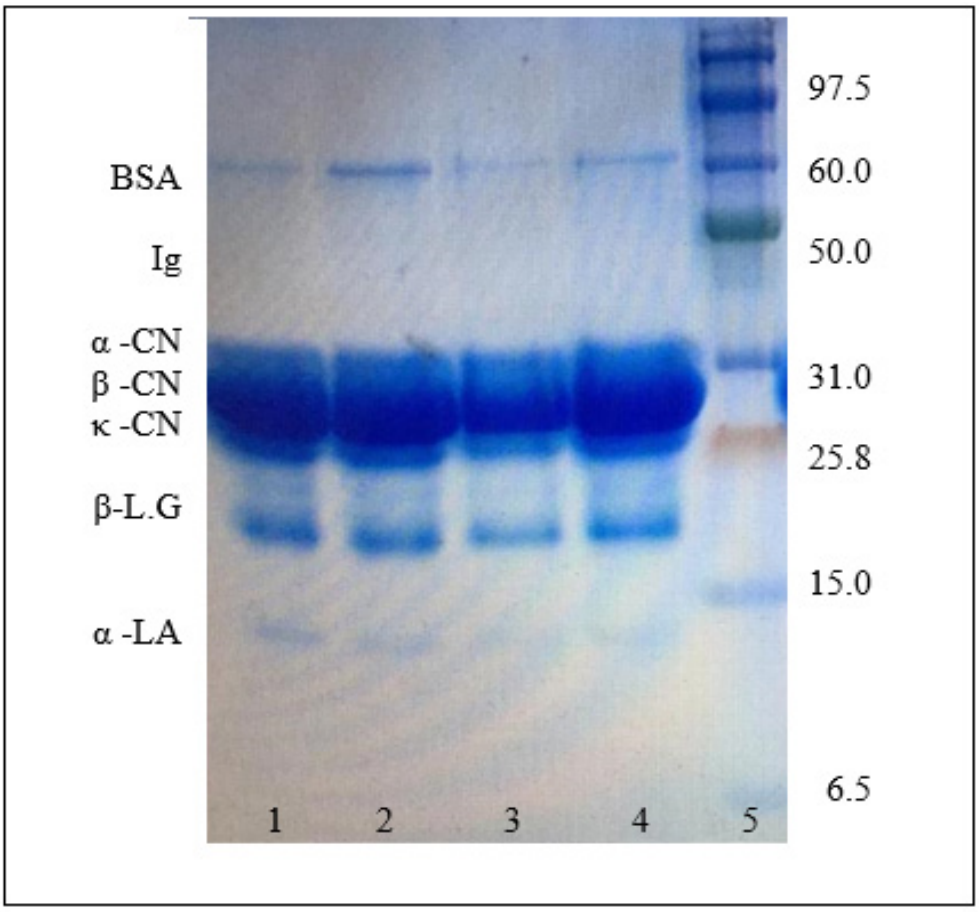


**Figure 2.** SDS-PAGE separation of proteins in karish cheese samples. Lane 1—control; lane 2—1 U; lane 3—1.5 U; lane 4—2 U; lane 5—molecular weight standard. BSA: Bovine serum albumin; Ig: Immunoglobulins; α-CN: α-casein; β-CN: β-casein; κ-CN: κ-casein; β-LG: β-lactoglobulin; α-LA: α-lactalbumin.

improved its manufacturing because the crosslinking proteins of TGase use the acyl exchange process to crosslink cysteine and lysine residues in a protein to create a proteinous network structure (Kumazawa & Miwa, 2009), which was visible in the organoleptic properties.

## 4. Conclusion

The use of TGase to crosslink proteins appears to be an efficient method of improving the techno functional features of karish cheese. TGase can synthesise high-molecular-weight polymers from milk proteins while preserving the chemical properties of karish cheese. The treatment of karish cheese with TGase increased gel firmness, which had a positive effect on karish cheese structure at the level 1.5–2.0 U $g^{-1}$ protein. These techniques have the potential to solve a wide range of production issues. In general, TGase treatment may be a suitable method for making modified karish cheese. The goal of this study was to improve the structure of karish cheese by utilizing a transglutaminase treatment. Physicochemical, microstructural, and organoleptic properties of karish cheese treated with TGase were studied and compared to cheese control samples that had not been treated with TGase. Comparison of results showed that the optimized cheese had a good structure. Lastly, our results are expected to pique dairy technologists and the cheese manufacturing industry in using TGase to enhance the structure of low-fat cheese.

## Conflict of Interests

The authors declare no conflict of interest.

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**Table 2.** Organoleptic properties of karish cheese samples.

| | Color and Appearance | Flavor | Body and Texture | Overall Acceptability |
|---|---|---|---|---|
| | **15** | **50** | **35** | **100** |
| Control | 13.8 [a] | 45.9 [a] | 28.1 [d] | 87.1 [c] |
| 1.0 U | 13.9 [a] | 45.7 [a] | 33.5 [c] | 94.9 [b] |
| 1.5 U | 14.3 [a] | 46.3 [a] | 34.7 [b] | 96.9 [a] |
| 2.0 U | 14.1 [a] | 46.1 [a] | 34.9 [a] | 97.1 [a] |

[a,b,c,d] Values in the same columns having different superscripts were significantly different ($p \leq 0.05$).

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## Siberian larch forest is spreading in the north, but at tundra's expense

The tundra is home to a unique community of flora and fauna. Experts are worried about the tundra being threatened to disappear by the climate changes.

Global warming is causing the temperature to be increasing rapidly. In the past 50 years, the temperature has risen by two degrees Celsius in the Arctic. This will cause severe consequences on the tundra as the Siberian larch forest is spreading steadily towards the north at the tundra's expense.

Researchers at the Alfred Wegener Institute are putting more effort into understanding the impact of global warming on the tundra. They developed a computer simulation of how larch forest woods could spread in the future. The results were not promising. Researchers concluded that only a third of the tundra could be saved even with determined climate protection measures. Furthermore, the worst scenario is that this unique flora and fauna could disappear entirely by the mid-millennium.

Researchers warn that if businesses continued the way it's being done nowadays, the Arctic ecosystem could disappear.

1. Stefan Kruse, Ulrike Herzschuh. **Regional opportunities for tundra conservation in the next 1000 years.** *eLife*, 2022; 11 DOI: 10.7554/eLife.75163

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# A first in human history: grown plants in soil from the Moon

In a new unique procedure, scientists have grown plants in a soil taken from the Moon. This is a first in human history.

A new study conducted by a team at the University of Florida showed how plants could be grown in a lunar regolith. The study also explores the biological response of the plants to the lunar regolith.

This is an important significant step toward producing vegetables or fruits on the Moon. With these results, this research will become a part of the Artemis Program, a human spaceflight program led by NASA and aims to return humans to the Moon.

Researchers did not predict these astonishing results; they were afraid that the seeds planted in the lunar soils would sprout. These results confirm that the lunar soils did not interrupt the hormones and signals involved in plant germination.

However, there are still differences between the plants grown in lunar soil and the control group, such as in the size of the plants and the speed of their growth.

"At the genetic level, the plants were pulling out the tools typically used to cope with stressors, such as salt and metals or oxidative stress, so we can infer that the plants perceive the lunar soil environment as stressful," said Anna-Lisa Paul, also one of the study's authors and a research professor of horticultural sciences in UF/IFAS. "Ultimately, we would like to use the gene expression data to help address how we can ameliorate the stress responses to the level where plants, particularly crops, are able to grow in lunar soil with very little impact to their health."

Nevertheless, questions such as: how will minerals in the lunar soil respond to having a plant grown in them, with the added water and nutrients? And will adding water make the mineralogy more hospitable to plants? still need to be answered.

1. Paul, AL., Elardo, S.M. & Ferl, R. **Plants grown in Apollo lunar regolith present stress-associated transcriptomes that inform prospects for lunar exploration**. *Commun Biol,* 2022 DOI: 10.1038/s42003-022-03334-8

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# Global plastic packaging waste: A burden that must be shared by both producers and consumers

Our planet is suffering from plastic packaging waste such as bottles, wrappings and bags being now everywhere. This plastic waste is polluting the global environment.

Plastic waste from all over the world is located at the Great Pacific Garbage Patch, an area twice the size of Texas. The floating waste breaks down into microplastics, which are consumed by fish and, in turn by humans who eat those fish.

New research shows that the biggest three suppliers countries for plastic waste are the U.S., Brazil, and China -- are the top suppliers of waste that generate together 41% of the world's production of plastic packaging waste. Europe is next with 24%, and Asia follows with 21%, most generated in China (12%). One of the most significant sources of plastic waste is high-protein food such as meat, fish, and dairy.

Every 1 kg of fish consumed will lead to an average of about 1.6 kg of waste, including not only the plastic bags but also trays, and cellophane used to wrap and cover the fish during transportation, storage, and sales. However, the plastic, in this case, would not be easy to replace as there is no other material that can protect the freshness of a food product that will be shipped around the world.

Therefore, this issue needs further developed technologies that make plastics more biodegradable as well as stricter regulations to discourage plastic packaging production and use. Producers can not bear this burden alone. Thus, consumers must share responsibility and costs. All parts along the supply chain need to be encouraged to reduce plastic use. Some examples are taxes on waste management, refunds for returning plastic bottles, banning plastic straws or imposing fees for grocery store plastic bags.

1. Xiang Gao, Sandy Dall'erba, Brenna Ellison, Andre F. T. Avelino, Cuihong Yang. **When one cannot bypass the byproducts: Plastic packaging waste embedded in production and export.** *Journal of Industrial Ecology,* 2022; DOI: 10.1111/jiec.13282

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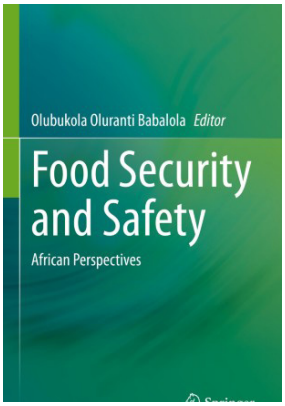


# Food Security and Safety: African Perspectives

A review by Nayram Ama Doe

Authors (Eds.): Olubukola Oluranti Babalola
Publisher: Springer Nature Switzerland AG
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*In recent times, especially in sub-Saharan Africa, food insecurity has been the main topic of discussion*. Sub-Saharan Africa faces malnutrition, poverty, insecurity and malnutrition, and climate change affecting agricultural productivity. Despite Africa's endowment with rich human and natural resources, there remains food insecurity in Africa. Food security in Africa can only occur if its residents have easy access to adequate, safe and healthy food to meet daily dietary requirements for a healthy life. Therefore, policymakers and African governments must adopt an all-inclusive approach to food security. This exciting book discusses different topics, such as harnessing the hidden treasures in an underutilized grain legume with food security potentials and indigenous food species' role in achieving food security in South-Eastern Nigeria. Also, functional meat and meat products for sustainable African nutrition security, innovative crops for climate change and food security in Africa, climate change, climate variability on food safety, foodborne diseases, and other topics are discussed.

This book begins with an introduction about Africa, being the most undernourished continent facing food insecurity. This situation poses the likelihood of facing a food crisis in the nearest future should critical measures not be taken to increase food production and reduce forest destruction. These acts promote releasing greenhouse gases, which increases climate change's adverse effect on food production. Furthermore, most African countries, especially developing countries, lack nutritious food required for dietary needs. However, these underutilized crops, such as the African yam bean, possess enormous nutritive benefits, and could enhance food security and reduce malnutrition.

Chapter one highlights food types and varieties' role in attaining food security in south-eastern Nigeria. Nigeria produces root tubers such as cassava, yam, cocoyam, and potato. Different species exist regarding the root tuber, yam, with white yam being the most consumed. The other species, water yam, three-leaved yams, and yellow yams, are neglected and underutilized. Utilizing these other yam species in various diets would achieve maximum food security. Chapter two of this book discusses various strategies required to exploit the potential of neglected orphan crops in improving food security in Africa. An exciting strategy is making local people partners to manage protected areas and using their knowledge extensively to manage resources sustainably. For instance, home gardens are excellent examples of managing traditional biodiversity and conservation. A well-advanced home garden with different horticultural classes leads to social, economic, and environmental benefits, thus improving soil conditions, giving the potential for intensive land utilization, subsistence farming, and biodiversity conservation, achieving food security in the long run.

Chapter three of this book focuses on the potential of finger millet for food security in Africa and how it could effectively be utilized in developing various food products and formulations. Finger millet possesses various potential regarding food and nutrition security because it is a high protein content food varying from 5.6% to 12.7%. In addition, according to FAO, finger millet contains 44.7% of essential amino acids, which is higher than the required percentage of amino acids of 33.9%. This crop is excellent in contributing to the nutritional status when consumed because it contains excellent proportions of other aromatic acids vital for human growth and health but is deficient in most cereals. The utilization of finger millet could be in different forms. These include fermented porridge, finger millet flour, weaning foods, composite flour, finger millet fritters, puffs, ragi soup, probiotic foods, and noodles. The advantages of these nutrients and



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various forms of utilization could go a long way in improving food and nutrition security.

The concluding chapter highlights food safety and security's dependence on soil quality since animals and plants depend on soils for nourishment. With a continuous increase in industrialization, human population and climate change, food security remains a challenge in Africa. Due to poor soil quality, there has been a significant decline in crop production, harvest and nutritional value, resulting in greater than forty per cent of Africa's food crisis. In addition, Nigerian soil productivity has reduced due to soil nutrient mining and insufficient fertilizer application, affecting food safety, quality and security.

Overall, this book was very informative and educative as it discusses and enlightens readers on African perspectives of food and nutrition security. In addition, it discusses in-depth various underutilized crops and strategies for using these crops to alleviate food and nutrition security. Therefore, this book is a good endorsement as a good read and a helpful resource.

Nayram Ama Doe is a master's student at the University of Kassel and Fulda University of Applied Sciences, Germany, studying International Food Business and Consumer Studies. Her research focuses on food sustainability, international food legislation, agriculture, and food systems, and she is very passionate about food security and food supply chain issues.

**About the author:**

Nayram Ama Doe is a master's student at the University of Kassel and Fulda University of Applied Sciences, Germany, studying International Food Business and Consumer Studies. Her research focuses on food sustainability, international food legislation, agriculture, and food systems, and she is very passionate about food security and food supply chain issues.

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