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INTERNATIONAL INDEXING

CONTENTS

Environmental Impacts of Menus Served in Two Different Seasons Vegan/Vegetarian and Traditional Turkish Food Restaurants: Comparison of Water Footprint

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Abstract

This research presents a comparative analysis of the water footprint and nutritional values of Vegan and Traditional Turkish restaurants. Conducted in May and July, this study extensively examines the water footprints of both restaurants during these months and the nutritional values of the menus they offer. According to the results of the water footprint analysis, the Vegan restaurant's blue water, grey water, green water, and total water footprint values are significantly lower than those of the Traditional Turkish Restaurant (May: $p<0.001$; July: $p<0.001$). The Traditional Turkish Restaurant's blue water footprint (May: 25.38, July: 41.93) is notably higher than that of the Vegan restaurant (May: 18.26, July: 16.18). Similar trends are observed in the grey water and green water footprint categories. Nutritional value analysis indicates that the energy content of Vegan restaurant menus is lower, but richer in fiber, iron, iodine, and vitamin B12 compared to Traditional Turkish restaurant menus. Particularly, the risk of vitamin B12 deficiency is prominent in Vegan restaurant menus (May: Traditional 8.1 µg, Vegan 0.1 µg; July: Traditional 7.5 µg, Vegan 0.1 µg). In conclusion, this study emphasizes the importance of eco-friendly practices and healthy eating options in the restaurant industry. Restaurant operators should review their water management strategies and take measures to enrich the nutritional content of vegan menus. Consumers should be informed about eco-friendly dietary choices. Without disclosing restaurant names and highlighting the differences between vegetarian and traditional cuisines, various recommendations have been provided for the sector.

Keywords: Water Footprint, Nutrient Analysis, Vegan Restaurants, Traditional Turkish Cuisine, Sustainability

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INTRODUCTION

Nutrition; being healthy, adequate, affordable, safe, and culturally acceptable is considered culturally acceptable for a balanced nutrition and health status (Fanzo, 2019). Sustainability concept first emerged with the report named "Our Common Future" by the World Commission on Environment and Development (WCED), working under the United Nations, in 1987 (Pekcan, 2019).

Decisions made after sustainable agriculture aim to avoid the excessive use and degradation of natural resources in the concept of sustainable nutrition (Smetena et al., 2019). Sustainable nutrition is a dietary approach that is protective and respectful towards biological diversity and ecosystems, culturally acceptable, accessible, economically fair and cost-effective; nutritionally adequate, safe, and healthy; and aims to optimize natural and human resources (Burlingame and Dernini, 2011). The development of the sustainable nutrition approach has been achieved by incorporating three main components: social, economic, and environmental (Smetena et al., 2019).

In recent years, the importance of this concept has been increasing in our country (Can et al., 2021). The sustainability aspects of sustainable nutrition models in Turkey are outlined in the Turkey Nutrition Guide (TUBER, 2022).

Recommendations:

• Reducing the consumption of animal protein sources, especially red and processed meat,

• Increasing the consumption of vegetables and fruits, • Increasing the consumption of plant-based foods such as legumes, nuts, whole grains, and diet rich in fiber,

• Reducing the consumption of packaged food products, • Minimizing food waste and, if possible, composting leftovers,

• Preferring the consumption of locally and seasonally grown foods (TUBER, 2022).

Various dietary models and preferred foods establish a connection between human health and sustainable environment worldwide. Diverse food policies, measures taken for food safety, and dietary guidelines incorporate approaches that focus on both human health and environmental health; emphasizing sustainable, economic, cultural, and social dimensions. Multiple paths are offered in nutrition to leave a healthy and sustainable environment for future generations (Olgun et al., 2022). In this context, sustainable nutrition dietary models have been developed. These dietary models address both human health and environmental health.

In the year 1842, a general definition of the vegetarian dietary style was introduced. The term "vegetarian" comes from the Latin origin "vegetus," which means healthy and lively (Akyol et al., 2022). The reasons for adopting this dietary pattern vary, ranging from ethical motivations and religious beliefs to environmental and cultural concerns, as well as considerations related to health (Dinu et al., 2017). Vegetarian nutrition excludes the consumption of all types of meat, fish, and seafood (Oussalah et al., 2020). Generally, it is associated with a higher dietary quality compared to non-vegetarian diets (Lee et al., 2020).

Vegetarians face challenges regarding the adequacy of nutrients and potential issues such as anemia, especially related to protein, calcium, iron, zinc, B12 vitamin, and D vitamin levels (Özcan & Baysal, 2016). However, studies have shown that individuals following a vegetarian diet tend to have a greater tendency for weight loss compared to those following a Western-style diet (Wang et al., 2023). Moreover, regular consumption of fruits and vegetables, according to meta-analysis results, is inversely associated with cardiovascular risk (Mcevoy et al., 2012). Clinical nutrition studies investigating the effects of a vegetarian diet on diabetic patients have shown significant reductions in fasting blood sugar and cholesterol levels. Despite these positive aspects, imbalanced vegetarian diets can lead to metabolic disorders and nutritional deficiencies (Özcan and Baysal, 2016).

Vegetarian nutrition is defined as dietary patterns determined by the level of intake of animal-based foods and can be categorized into various subtypes (Lee et al., 2020). The vegetarian diet is divided into five different subtypes. The diet subtypes are illustrated in Figure 1.

In 1847, the Vegetarian Society, established in England, decided not to include semi-, pesco-, and pollo-vegetarianism within the scope of vegetarian diets due to the consumption of animal meat (Tuncay, 2018). Vegetarian nutrition and its types can be adopted by individuals for reasons such as a healthy lifestyle, rapid transformation in the food system, changes in lifestyle, and personal preferences (Sezgin et al., 2023).

Studies have shown that the consumption of processed products is minimized in vegetarian diet types, which are rich in plant-based nutrients. The adoption of vegetarian diets has been associated with a reduced risk of various chronic diseases, including cardiovascular diseases, diabetes, hypertension, cancer, and dementia (Wang et al., 2023). Additionally, for women in both pre- and post-menopausal periods, the implementation of lacto-ovo vegetarianism is recommended for the balanced regulation of lipid levels (Tuncay, 2018).

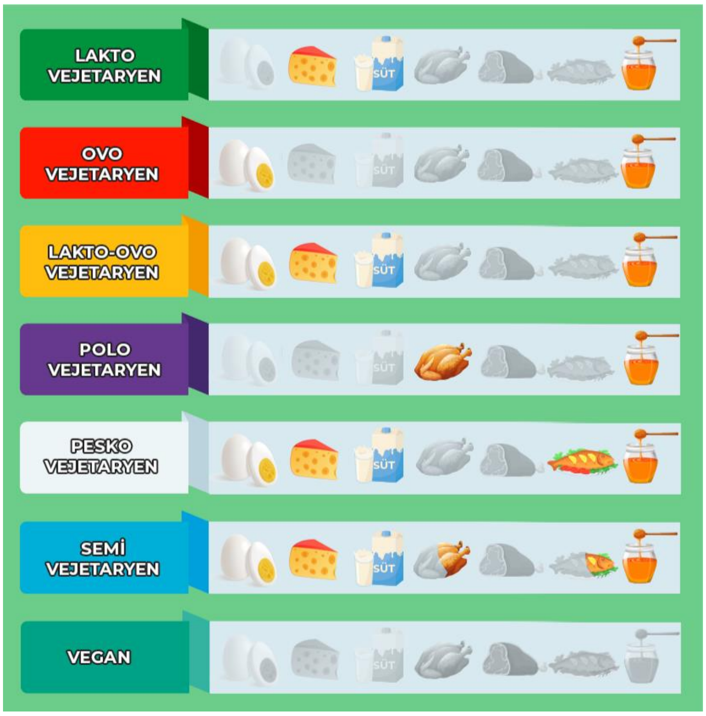

Figure 1. Consumed and Not Consumed Food Groups for Different Types of Vegetarian Diets

Today, there are many dietary guidelines recommending increasing the consumption of plant-based foods while reducing the consumption of animal-based foods. Vegan nutrition plays a significant role in this approach (Dikme, 2023). Vegetarians and vegans are often thought of solely as individuals who do not consume meat. However, this viewpoint is highly inadequate in explaining the underlying social reality of vegetarianism. The word "vegan," meaning to be opposed to the consumption of animal products, was coined by Donald Watson, the founder of the Vegan Society in Turkey, in 1944 (Güler and Çağlayan, 2023). Vegan nutrition, the seventh subtype of vegetarianism, is considered more of a lifestyle and ethical approach than just a dietary type (Akagündüz and Altun, 2023).

Vegans abstain from consuming animal-derived products such as meat, poultry, fish, honey, milk, eggs, yogurt, and other animal-based items (Ucan and Bozok, 2019). Additionally, they avoid using clothing made from animal products like wool, silk, and leather, and are opposed to products tested on animals. Beyond dietary preferences, individuals embracing this lifestyle are referred to as ethical vegans, as their principles extend to all aspects of daily life, distinguishing them from mere dietary vegetarians (Tuncay, 2018). Vegans address their nutritional needs by balancing the intake of soybeans, legumes, and oily seeds as alternative protein sources (İpekci and Toktas, 2021). Ensuring diversity in the consumption of nutrients, especially essential amino acids, is crucial. While animal-based foods provide sufficient essential amino acids, plant-based foods have limited amounts. Hence, vegans need to diversify their meals to meet essential amino acid requirements. Omega-3 fatty acids are found in lower quantities in vegan diets compared to omnivorous diets. Vegans may lack omega-3 fatty acids from fish and have higher omega-6 fatty acids from plant-based oils (TUBER, 2022).

Vegan diets are rich in dietary fiber, magnesium, folate, vitamin C, vitamin E, non-heme iron, and Phytochemicals. However, they are deficient in vitamin D, calcium, zinc, vitamin B12, saturated fat, heme iron, cholesterol, and omega-3 fatty acids (Craig, 2009). Research indicates that women are more prone to iron deficiency anemia than men among vegan individuals (Tatlı, 2022). A well-planned and supplemented plant-based diet, tailored to individual needs and supported by a schedule, can be suitable for individuals at all stages of the life cycle (Wang et al., 2023).

EAT-Lancet Commission, in January 2019, defined a planetary health diet as a healthy dietary pattern aimed at reshaping global food systems for environmental sustainability and improving human health. The commission's goal is to develop a dietary system that preserves the health of individuals and natural resources by 2050. This developed dietary pattern is based on the strongest evidence to achieve global scientific goals for healthy nutrition and sustainable food production. It works within safe boundaries to support the United Nations Sustainable Development Goals.

The planetary health diet primarily consists of abundant plant-based foods such as whole grains, fruits, vegetables, nuts, legumes, and limited amounts of animal-derived foods, refined grains, processed foods, and added sugars. Additionally, the diet is flexible, allowing small amounts of fish, meat, and dairy products as optional choices. In summary, it is a predominantly plant-based diet with the flexibility to include limited amounts of fish, meat, and dairy, depending on personal preferences (Dalile et al., 2022).

Water Footprint

The basic resource that sustains the lives of all living beings is water. However, it is believed that pollution (air, water, environment) and climate change, along with rapid population growth, will render the available water resources insufficient to meet the demand (Chapagain and Hoekstra, 2007). The water footprint is a concept that measures the amount of freshwater required throughout the supply chain to produce a good or service. This approach exists to support decisions regarding various alternative processes and products, aiming for more effective water management, including its usage and allocation (Turan, 2017). Developed by Arjen Hoekstra, this concept integrates both direct water consumption and the water embedded in the products consumed. It has become a valuable tool for assessing the environmental impact of water use and promoting sustainable water management (Mekonnen and Hoekstra, 2011).

Water footprint calculations provide insights into the environmental effects of water use in the production and consumption of goods and services. They consider three key components: blue, green, and grey water footprints.

1. Blue Water Footprint: The blue water footprint accounts for the consumption of freshwater from surface or groundwater sources (Erdogan, 2018). Consumptive water use is identified through four conditions: water evaporation, water embedded in products, water not returning to the same water area (e.g., directed elsewhere or to the ocean), and water not returning during the same period (e.g., withdrawn during a low-water period and returned during a high-water period). While evaporation is often the primary factor, the other conditions are included when relevant (Hoekstra et al., 2009). This metric provides a measure of the amount of consumable freshwater available to humans. The blue water footprint is used in agricultural production, industrial processes, and domestic activities (Oztas and Artar, 2021).

2. Green Water Footprint: The green water footprint represents the volume of rainwater consumed during the production process, particularly in agriculture and forestry (Demir, 2023). It considers the evapotranspiration of total rainwater and rainwater harvested for crops. Distinguishing between blue and green water use is crucial due to the differing impacts of surface and groundwater use compared to rainwater use (Hoekstra et al., 2009).

3. Grey Water Footprint: The grey water footprint serves as an indicator of pollution, demonstrating the volume of ambient water needed to assimilate pollutants (Muratoglu, 2019). This metric is based on water quality standards and estimates the amount of freshwater needed to neutralize or reduce pollution loads (Pegram et al., 2014).

Carbon Footprint

The carbon footprint is another essential indicator for sustainable development, focusing on the ecological impact of carbon dioxide (CO2) emissions associated with various activities (Ozsoy, 2015). The carbon footprint can be examined under two main categories: personal and corporate (Bekiroglu, 2011). The food footprint of consumers represents their lifestyles and the relationship between their consumption patterns and the environment (Guven and Aysel, 2016). It considers the natural resources used in the production of agricultural, livestock, fishing, and forestry products. The carbon footprint highlights the need for a biologically productive area to offset these emissions, contributing to climate change (Tatlı, 2022).

Sustainable Development Goals

The United Nations has established the Sustainable Development Goals (SDGs) to address global challenges and promote sustainable development. These goals include ensuring health, ensuring food security, eradicating hunger, achieving environmental sustainability, and supporting sustainable agriculture. (Meltzer et al, 2019; Peskircioglu, 2016). Key elements for success in these goals include providing nutritious food for all, reducing non-communicable diseases, and addressing climate change (Gedik, 2020).

To put these principles into action, efforts are required to manage water resources sustainably, reduce carbon footprints, and achieve the targets outlined in the SDGs. By understanding and implementing the concepts of water and carbon footprints, individuals and societies can contribute to a more sustainable and resilient future.

MATERIAL and METHOD

This descriptive study was conducted by obtaining daily food product and raw material inputs twice, in two different seasons, from Vegan Istanbul, a restaurant serving on the European side in Beyoglu district, and Nilce Lezzetler, a restaurant serving traditional Turkish cuisine located in Beykoz district on the Anatolian side of Istanbul. These restaurants were selected based on the researcher's oral discussions, approvals, and accessible opportunities. With the support of the project, written permission was obtained from the restaurants just before starting the study. Subsequently, food raw material inputs were collected from both restaurants on May 20-25, 2023, and July 10-17, 2023. During these dates, the researcher visited the respective restaurants to gather precise information about the inputs. To calculate the water footprint of the obtained food raw materials, the methodology developed by Hoekstra et al was referenced and utilized. Raw materials without a water footprint value were excluded from the calculations.

Calculation of the Water Footprint: Mekonnen and Hoekstra (2011) created average water footprint factors for various foods, including Turkey. According to the data in the study titled 'Evaluation of Different Diet Models in Terms of Carbon and Water Footprint within the Framework of Sustainable Nutrition Concept' conducted by Tatlı (2022), diet models with more animal-sourced foods were found to have higher greenhouse gas emissions and water footprints. The water footprint factors determined for foods produced in Turkey in this study will be used. In studies where the water footprint was calculated, water footprint factors for plant-based foods were determined by calculating the daily water balance of soil crops. The crop coefficient, dependent on the growth stage of the plant, changes over time. Water footprint for animal-sourced foods will be calculated based on the animal's consumption of feed, drinking water, and water for services. Water required for services includes water used to clean the animal's living space, bathe the animal, and perform services necessary for environmental protection. The water footprint of meat products and milk and dairy products will also be calculated based on the average production of the animal. The average water footprint factors of the foods in the menus will be calculated for all menus (a weekly daily menu obtained from both restaurants in two different seasons) by multiplying them with the quantities present in the diet.

Entry of Foods into the System: The energy and nutrient content of the obtained menus were detailed by examining them with the Nutritional Information System (BeBiS) 9 professional version. The daily total energy, carbohydrates, protein, fat, dietary fiber, cholesterol, B12 vitamin, iron, and iodine intake levels of the restaurant menus were determined.

Statistical analyses of the obtained data were conducted using IBM SPSS 25.0 statistical software package. For the analysis of data, descriptive statistical methods were employed, including percentage (%) and number of units (n) for qualitative variables; standard deviation (SD) and arithmetic mean ($\bar{X}$) for quantitative parametric variables; and median (Xmed), lower value, and upper value for quantitative non-parametric variables. The normal distribution of variables was examined through visual methods (histograms and probability plots) and analytical methods (Shapiro-Wilk test).

For correlation analyses to examine relationships between variables, "Pearson" correlation coefficients were calculated for variables showing normal distribution, and "Spearman" correlation coefficients were calculated for those not showing normal distribution. All statistical analyses were evaluated at a confidence interval of 95%, and a significance level of $p<0.05$. Additionally, in the clustering analysis where categorical/qualitative and quantitative variables were examined together, the hierarchical method "Two-Step Cluster" was employed, and importance prediction degrees were calculated. After the preliminary evaluation of the data, decisions were made regarding the use of possible advanced statistical analysis methods.

RESULTS and DISCUSSION

In this part of the study, the average water footprints of traditional and vegan dishes served by Veganİstanbul restaurant, which offers vegan meals, and Nilce Lezzetler Restaurant, which offers traditional Turkish cuisine, during the month of May, are compared.

Table 1. The comparison of water footprints between the vegan restaurant and the traditional restaurant (May, 2023)

Variables	Type	N	$\bar{X}$	Ss	*t*	*p*
Blue water	Traditional		25,38	5,33	15,797	.0000***
	Vegan		18,26	6,55		
Grey water	Traditional		27,11	6,92	12,996	. 0000***
	Vegan		17,64	3,41		
Green water	Traditional		339,55	92,05	12,235	.0000***
	Vegan		139,55	15,90		
Total water (May)	Traditional		392,04	91,48	14,214	.0000***
	Vegan		175,36	21,65		

It was determined that there is a significant difference between the blue, grey, and green water footprints of Veganİstanbul restaurant, which serves vegan meals, and Nilce Lezzetler Restaurant, which serves traditional Turkish cuisine, during the month of May. And along with this It was determined that in May, the restaurant serving traditional dishes had higher blue, grey, and green water footprints compared to the restaurant serving vegan meals.

In this part of the study, the average water footprints of traditional and vegan dishes served by Vegan İstanbul restaurant, which offers vegan meals, and Nilce Lezzetler Restaurant, which offers traditional Turkish cuisine, during the month of July, are compared.

Table 2. The comparison of water footprints between the vegan restaurant and the traditional restaurant (July, 2023).

Variables	Type	N	X̄	Ss	*t*	*p*
Blue water	Traditional		41,93	12,49	11,133	.0000***
	Vegan		16,18	5,10		
Grey water	Traditional		33,56	9,60	11,597	.0000***
	Vegan		12,64	1,63		
Green water	Traditional		456,50	72,17	20,979	.0000***
	Vegan		109,18	15,97		
Total water (July)	Traditional		531,99	72,62	24,296	.0000***
	Vegan		138,00	16,57		

It was determined that there is a significant difference between the blue, grey, and green water footprints of Vegan İstanbul restaurant, which serves vegan meals, and Nilce Lezzetler Restaurant, which serves traditional Turkish cuisine, during the month of July. And along with this It was determined that in July, the restaurant serving traditional dishes had higher blue, grey, and green water footprints compared to the restaurant serving vegan meals. So, according to the analyses conducted, it has been determined that the traditional restaurant has a higher water footprint than the vegan restaurant both in May and in July.

Table 3. Vegan and Traditional Restaurants Recommended Daily Allowances (RDA) values for the daily intake (According to the Nutrition Information System (Bebis))

Age/ Gender	19-24 Years of Female				19-24 Years of Male				40-49 Years of Female				40-49 Years of Male			
Months	May		July		May		July		May		July		May		July	
Restaurant Type	TRADITIONAL	Vegan	TRADITIONAL	VEGAN	TRADITIONAL	VEGAN	TRADITIONAL	VEGAN	TRADITIONAL	VEGAN	TRADITIONAL	VEGAN	TRADITIONAL	VEGAN	TRADITIONAL	VEGAN
Energy	48	44	51	48	42	37	43	40	47	46	53	50	39	38	44	41
CHO %	24	30	31	31	21	26	26	26	23	31	32	32	19	26	27	27
Protein %	54	39	62	44	47	33	52	37	52	41	64	46	44	34	53	38
Fats %	92	71	84	81	79	60	70	68	89	74	87	84	74	62	72	70
Fiber %	35	71	50	77	35	72	50	77	35	72	50	77	35	72	50	77
Cholesterol (mg)	91,1	0,1	99,3	0,2	91,1	0,1	99,3	0,2	91,1	0,1	99,3	0,2	91,1	0,1	99,3	0,2
B12	186	4	202	4	186	4	202	4	186	4	202	4	186	4	202	4
Iodıne	42	29	52	29	42	29	47	29	42	29	47	29	42	29	47	29
Iron	42	86	47	90	61	125	76	130	61	125	76	125	61	125	76	130

Nutritional value analysis indicates that the energy content of Vegan restaurant menus is lower, but richer in fiber, iron, iodine, and vitamin B12 compared to Traditional Turkish restaurant menus. Particularly, the risk of vitamin B12 deficiency is prominent in Vegan restaurant menus (May: Traditional 8.1 µg, Vegan 0.1 µg; July: Traditional 7.5 µg, Vegan 0.1 µg).

CONCLUSION

In conclusion, this study emphasizes the importance of eco-friendly practices and healthy eating options in the restaurant industry. Restaurant operators should review their water management strategies and take measures to enrich the nutritional content of vegan menus. Consumers should be informed about eco-friendly dietary choices. Without disclosing restaurant names and highlighting the differences between vegetarian and traditional cuisines, various recommendations have been provided for the sector.

The findings mentioned indicate that vegan nutrition can offer a significant advantage in terms of environmental sustainability. This is because vegan nutrition has the potential to reduce water consumption and resource usage stemming from the consumption of animal products. Particularly, it is known that traditional meat and dairy production have adverse effects not only on water but also on land use, greenhouse gas emissions, and biodiversity. Promoting and adopting vegan meal options can be a significant strategy with the potential to reduce environmental impact. This is important not only for restaurants and individuals but also for consumers to embrace more sustainable and environmentally friendly dietary habits.

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REFERENCES

Akagündüz H. & Altun, Ö. 2023. Vegan/vegetarian flavors: a case of restaurants operating in north Cyprus. *Journal of Turkish Tourism Research*, 7(3), 417-431.

Akyol N., Kaya M. & Seçim Y. 2022. Vegetarian diets, *Journal of Social, Humanities and Administrative Sciences,* 5(1), 66-82.

Bekiroğlu O. 2011. The New Rule of Sustainable Development, II. National Congress of Electrical Installations.

Burlingame B. & Dernini S. 2011. Sustainable diets: the mediterranean diet as an example. *Public health nutrition*, 14(12), 2285-2287.

Can B., Bayram H.M., Öztürkcan S.A. 2021. Solution recommendations for environmental problems: overview of current sustainable nutrition practices. *Gıda,* 46(5), 1138-1157.

Chapagain A, K. & Hoekstra A.Y. 2007. The Water Footprint of Coffee and Tea Consumption in the Netherlands. *Ecological Economics*, 64(1), 109-118.

Craig W. J. 2009. Health Effects of Vegan Diets. *The American journal of clinical nutrition,* 89(5), 1627–1633.

Dalile B., Kim C., Challinor A., Geurts L., Gibney E. R., Galdos M. V., La Fata G., Layé S., Mathers J. C., Vauzour D., Verkuyl J. M. & Thuret S. 2022. The EAT–Lancet reference diet and cognitive function across the life course. *The Lancet Planetary Health*, 6(9), 749-759.

Demir Y. 2023. Evaluation of water footprint in beef production. *Aydın Gastronomy*, 7(1), 161-171.

Dikme G. T. 2023. Vegan nutrition in the elderly.*Acta Medica Ruha.*, (2), 173-183.

Dinu M., Abbate R., Gensini G. F., Casini A. & Sofi F. 2017. Vegetarian, vegan diets and multiple health outcomes: a systematic review with meta-analysis of observational studies. *Critical Reviews in Food Science and Nutrition*, 57(17), 3640-3649.

Erdoğan P. 2018. Determination of greenhouse gas emission and water footprint of turkish cuisine. *Master Thesis. Hacettepe University Graduate School of Health Sciences.* Istanbul.

Fanzo J. 2019. Healthy and sustainable diets and food systems: the key to achieving sustainable development goal. *Food Ethics,* 4(2), 159-174.

Gedik Y. 2020. Sustainability and sustainable development with social, economic and environmental dimensions. International *Journal of Economics, Politics, Humanities & Social Sciences.* 3(3), 196-215.

Gökçen M., Aksoy Y. C. & Ateş Özcan B. 2019. Overview of vegan nutrition in regards to health. *Journal of Health and Life Sciences*, 1(2), 50–54.

Güler O. & Çağlayan G. D. 2021. How did I become vegan? A phenomenological qualitative research, *Journal of Contemporary Tourism Research*, 5(2), 287-304.

Güven G. & Aysel İ. 2016. Food footprint in daily life: opinions about the consumption of convenience food. *Theory and Practice in Education*, 12(2), 403-426.

Hoekstra A. Y., Chapagain A. K., Aldaya M. M. & Mekonnen M. M. 2009. Water Footprint Manual. Report. 192.

İpekçi D. & Toktaş N. 2021. Eating habits and sportive performance of vegan athletes. *Spormetre The Journal of Physical Education and Sport Sciences, 19(4), 20-42.*

Lee K. W., Loh H. C., Ching S. M., Devaraj N. K., Hoo F. K. 2020. Effects of vegetarian diets on blood pressure lowering: A systematic review with meta- analysis and trial sequential analysis. *Nutrients*, 12(6).

McEvoy C. T., Temple N. & Woodside J. V. 2012. Vegetarian diets, low-meat diets and health: a review. *Public Health Nutrition* 15(12), 2287-2294.

Mekonnen M. M. & Hoekstra A. Y. 2011. The Green, Blue and Grey Wate0r Footprint Of Crops andDerived Crop Products. *Hydrology and Earth System Sciences*, 15(5), 1577-1600.

Meltzer H. M., Brantsæter A. L., Trolle E., Eneroth H., Fogelholm M., Ydersbond T. A. & Birgisdottir B. E. 2019. Environmental sustainability perspectives of the nordic diet. *Nutrients*, 11(9).

Muratoğlu A. 2019. Assessment of water footprint of production: a case study for diyarbakır province. *Journal of the Faculty of Engineering and Architecture of Gazi University,* 35(2), 845-858.

Olgun S. N., Manisalı E. & Çelik F. 2022. Sustainable Nutrition and Dietary Models. *BANU Journal of Health Science and Research,* 4(3), 261-271.

Oussalah A., Levy J., Berthezène C., Alpers D. H. & Guéant J. L. 2020. Health outcomes associated with vegetarian diets: an umbrella review of systematic reviews and meta-analyses. *Clinical Nutrition*, 39(11), 3283-3307.

Ozcan T. & Baysal S. 2016. Vegetarian diet and effects of vegetarian nutrition on health. *Journal of Agricultural Faculty of Uludag University*, 101-116.

Özsoy E. C. 2015. Low-carbon economy and carbon footprint of turkey. *Journal of International Labor and Society,* 4(9), 198-215.

Öztaş Karlı R. G. & Artar M. 2021. Water footprint and blue-green infrastructure as a tool in urban water management. *Journal of Ege University Faculty of Agriculture*, 58(1), 145-162.

Pegram G., Conyngham S., Aksoy A., Dıvrak B.B. & Öztok D. 2014. Turkey's water footprint report: water, production and international trade, *Worldwide Fund for Nature* 1(1), 20-23.

Pekcan, G, A. 2019. Sustainable diets and dietary pattern: plant-based nutrition. *Journal of Nutrition and Dietetics*, 47(2), 1–10.

Peşkircioğlu, N. 2016. 2030 Sustainable development goals: towards a global productivity movement. *Anahtar Journal*, 335, 4-6.

Sezgin A., Eroğlu F. E. & Şanlıer N. 2023. Comparison of sustainable nutrition models. *Turkish Journal of Agriculture- Food Science and Technology*, 11(3), 603-616.

Smetana S. M., Bornkessel S. & Heinz V. 2019. A Path From Sustainable Nutrition To Nutritional Sustainability Of Complex Food Systems. *Frontiers in Nutrition*. 6(39), 1-6.

Tatlı M. 2022. Evaluation of Different Diet Models In Terms of Carbon And Water Footprint Within The Concept of Sustainable Nutrition. Master Thesis. Biruni University, Istanbul, Turkey.

Republic of Türkiye Ministry of Health (TUBER.) 2022. Ministry of Health, General Directorate of Public Health, Ankara (1031).

Tuncay G. Y. 2018. Health-wise vegan/vegetarianism. *Eurasia Journal of Health Sciences*, 1(1), 25-29.

Turan S. E. 2017. An evaluation of Turkey's water footprint. T*urkish Bulletin of Hygiene and Experimental Biology, 74, 55-62.*

Uçan Z. B. & Bozok D. 2019. Veganism and Gastronomy. IV.Internatıonal Gastronomy Tourism Studies Congress 19-21 September Nevşehir.

Wang T., Masedunskas A., Willett W. C. & Fontana L. 2023. Vegetarian and vegan diets: benefits and drawbacks. *European Heart Journal*, 44(36), 3423–3439.

The Impact of Global Warming on The Food Crisis in Africa

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Abstract

Global warming is the main factor which causes changes in climate and it occurs by release of industrial gases in the atmosphere and increasing the earth temperature. Climate change concerns and its effects on food safety are highly predictable in many regions of the world, involving Africa. Africa's food issue is greatly made worse by global warming, which has an impact on socioeconomic stability, animal health, and agricultural output. The growth of crops is disrupted and the yields of basic crops like maize, wheat, and rice are decreased by rising temperatures and changed precipitation patterns. Infrastructure and agricultural productivity are further threatened by an increase in the frequency and intensity of extreme weather events, such as floods and droughts. Warmer temperatures can increase the range and activity of agricultural pests and diseases, which causes extensive crop loss. Additionally, water scarcity and heat stress affect livestock, which lowers output. These climate-related issues drive up food costs, increase food insecurity, and may lead to migration and resource-related conflict. Climate-resilient crops, better water management, sustainable agricultural practices, and investments and policies that support them are all necessary to mitigate these effects. To improve resilience and guarantee food security in Africa in the face of the persistent danger of global warming, a comprehensive strategy is required.

Keywords: Global warming, Climate change, Agricultural productivity

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INTRODUCTION

Global warming is the main factor which causes changes in climate and it occurs by release of industrial gases like methane, carbon dioxide, nitrogen oxides and ozone gases continuously in the atmosphere and increasing the earth temperature (Bagdatli and Belliturk, 2016; Bagdatli and Arslan, 2020; Bagdatli and Can, 2020). Increasing Population is also a significant factor for climate variability will cause many problems for global food supply and several nutritional problems could arise in the nearby future. Water, is the fundamental element, for survival of living beings. Rainfall and precipitation are both sources of water and many life events depends on these factors like living life, Agricultural production, living migration and urbanization (Bagdatli and Arslan, 2019; Elsheikh et al., 2022a).

According to scientists, climate is the air that could modify in the atmosphere, means climate known as collection of different atmospheric actions. Generally, Change in climate means variations in weather for centuries which can be occur naturally or by human actions (Elsheikh et al., 2022b; Bagdatli and Arikan, 2020). These Global climate changes, can be negatively impacted on different atmospheric areas by emitting carbon dioxide in the air (Bagdatli and Can, 2019).

Global climate change poses a threat to it due to rising carbon emissions and the greenhouse gas impact. One of the fundamental components of life is carbon. However, the protecting impact of the bard layer is diminished and inconsistencies in temperature and precipitation are brought about by the steady increase in CO_2 levels in the atmosphere due to human demands and consumption. Research indicates that there will be a 0.1°C rise in temperature every ten years (Bağdatlı and Arıkan, 2020; Bağdatlı and Ballı, 2020a). Global warming is brought on by an increase in CO_2 and other gases in the atmosphere because of industrial activity. Hydrological catastrophes are accelerated by this warming, and it is anticipated that this will lead to an increase in extreme weather events including droughts and floods as well as climate change (Bağdatli et al., 2022).

Food production and assembly is a serious component which can be effected by changing in climate (Bagdatlı et al., 2023). Another important component is an upsurge in sea-level because of changes in climate, leads to the destruction of forests which are key source of food in many countries (Afreen et al., 2022). Global climatic variability produce open surface evaporation inclines to upsurge in temperatures and precipitation, which are very important factors for living lives, will cause continuing reduction of water assets, endangerment of natural life, and have bad effects on agricultural production. Plants growth also effected by climatic variability, which also involve drought and land degradation leads to less agricultural production (İstanbulluoğlu et al., 2013; Bağdatlı and Ballı, 2019).

CLIMATE CHANGE EFFECTS ON AGRICULTURE

As the world's population approaches 8 billion people, it will become increasingly difficult for humanity to meet the expanding population's food demands. Uncontrolled changes in weather factors like temperature and precipitation have a detrimental impact on agricultural productivity. According to Bağdatli et al. (2015), a few of these detrimental impacts include soil erosion caused by water, changes in pH levels, increased salinity, and nitrogen leaching. Climate change concerns and its influence on food safety are increasingly predictable in numerous regions of the world, involving Africa. Many studies developed that Africa is characterized as the utmost susceptible land to climate changes (Bwalya, 2013; IPCC, 2007; Liliana, 2005; Vogel, 2005; World Bank, 2016). The main observation of that studies was changes in climate have a harsh effect on cultivated land, which eventually disturbs food safety. The Inter-governmental panel on climate change indicates that Southern Africa has greater susceptibility to climate change and expects severe consequences, which employing extensive influences on the people livelihoods (IPCC, 2007).

Conferring to the IPCC (2007), productivity of agriculture will decrease in 2080 from 21% - 9% because of climatic variability in sub Saharan Africa. Agriculture is the major key for economic development in Sub-Saharan Africa, where it contributes more than 40% of the Gross Local Product for utmost countries and hiring more than 50% people in those countries. Additionally, agriculture works as the central base for food safety in the state as the mostly people cultivate their personal food (Barrios et al., 2008).

Foods obtained from Agriculture remain sensitive to climate variability, harshness and occurrence rate of extreme climatic conditions (Wheeler and Von Braun, 2013; Challinor et al., 2007). There are two types of effects occur on agriculture due to changes in climate involve biophysical and socio-economic effects. Biophysical effects comprise changes in quality and quantity on water and land resources; while physiological effects comprise quality and quantity of agricultural crops, pasture, forests, and livestock; augmented challenges of weeds, pests, and diseases (FAO, 2007). The minimum and maximum soil temperature needs of the plants to be farmed should be considered to guarantee optimal agricultural yield. For instance, excessively hot soil temperatures in tropical regions can cause several plant illnesses and excessive water consumption, which can result in plant mortality (Bağdatlı and Ballı, 2020b).

The biophysical effects concerns on changes on production conditions of agricultural crops, production of livestock, and fisheries because of growing temperatures, inconsistency in rainfall patterns, frequency and intensity of other extreme natural events. For instance, the production period of agricultural crops might be influenced by climate change through varying suitability of production situations of agricultural crops and limiting the duration of the production period (Nhemachena et al., 2016). Socio-economic effects due to climate change include several factors like reduced production and yields; reduced GDP of agriculture; improved hunger and risks of food security; variations in trade configuration and systems all through states; instabilities in prices of world foodstuff; and migration conflict (FAO, 2007). These factors affect achievement of maintainable development objectives, mainly those associated to agriculture.

In this article we are discussing about global warming effects on food safety in Africa. Distinct effects of climate change on agriculture food schemes were experienced through many locations on the basis of warming severity and fluctuations in rainfall distribution and patterns, higher intensity and occurrence of floods and droughts (Wheeler and Von Braun, 2013; Olmstead, 2014; Arnell et al., 2011). Additionally, the varying climate intensifies hydrologic variability and water stress particularly in arid and semi-arid and states of Southern Africa (Rosenzweig et al., 2014). From previous studies it was indicated that approximately two-thirds part of Africa's agricultural land is anticipated to be vanished by 2025 due to shortage of rainfall and drought because South Africa is not resistant to these influences (Liliana, 2005). It is assessed that 95 percent land of Africa's agriculture is rain fed which makes it highly susceptible to climate change. The growing frequency of scarcities because of climate change predicted to decrease agricultural yield by up to 50 percent in Africa in 2020 (Dube et al., 2016). It was also identified that the long-lasting trend of increasing temperature produced a negative effect on agricultural production for the long duration (Bağdatli et al., 2014).

It was found that Southern Africa state would face adverse influences on many major crops like wheat, maize and sugarcane due to augmented warming and reductions in rainfall (Lobell et al., 2008). Cereal crop production is estimated to decrease considerably in countries including Ethiopia, Zimbabwe, Nigeria and Sudan. It is expected that in 2050, yields of crop have fallen through up to 20%, and by means of 2100 crop profits in South Africa are estimated to have fell down up to 90% (Hope, 2006).

It was documented in 2009 by European Commission report that climate variability in Africa will decrease crop productivity and in consequently price of food will increase that would force communities to change consumption and production patterns. Numerous studies have enumerated the direct influence of climate variability on production of agriculture (Asseng et al., 2015) markets (Nelson et al., 2014; Lotze-Campen et al., 2014; Von Lampe et al., 2014) and food security (Baldos and Hertel, 2014; Hasegawa et al., 2014). For instance, a latest model of profitable comparison study on global agricultural (Nelson et al., 2014) establish that upcoming climate variability will decrease yields of major crop by 17%, which automatically will rises market prices up to 20% and lessens consumption up to 3% in 2050, after alteration of production crosswise regions.

AGRICULTURAL YIELD AND FOOD SAFETY

Africa has mostly dependent on agriculture for its economic growth, decreasing poverty, and increasing nutrition and food security (FAO, 2014). Agriculture is controlled by small holders who subsidize up to 90 percent of agricultural yield in the constituency (Brown et al., 2018). There is a solid link among natural ecosystem, climate, and African agriculture. Ecosystem facilities and biodiversity are used as many resolutions for maintainable upsurges in agricultural production in Africa which provides both better products for nutrition and food security and lessen climate externalities (Barrios et al., 2018; Bommarco et al., 2018). Those regions which have advanced level of biodiversity usually are most resistant to environmental variations and enhanced agricultural productivity (Winfree and Kremen, 2009). On contrary if natural ecosystems become destroyed decreases their ability to regulate water accessibility, soil foundation, and nutrient and energy flow (Bommarco et al., 2018; Georg et al., 2018).

Most countries of Africa, being affected by higher temperature and precipitation variation in the constituency. For instance, since 1996 to 2003, a decline in rainfall was observed in most regions of Africa which consequently caused decline in long duration crops like slowly developing varieties of sorghum and maize. Long duration crops rely upon rain throughout this normally wet season and advanced moisture insufficiency results in less crop productivity, thus affecting the obtainable food supply (Funk et al., 2005).

It was stated that most African countries have little adaptive capability, topographical and geographical locations make the constituency extremely susceptible to crop failure because of adverse effects of climate variability (Gebreegziabher et al., 2011; Evangelista et al., 2013). Crop productivity present a strong correspondence with climate variability and by the extent of cold or heat waves and fluctuation depend on plant developing stages throughout extreme weather happenings (Hoffmann, 2013).

Changing pattern of precipitation will increase water scarceness and linked drought stress meant for crops and change irrigation water sources. They also decrease the probability for farmers' future planning (OECD, 2014), indirectly, a variation in moisture and temperature levels might lead to a modification in the immersion level of fertilizers and additional minerals, which regulate yield outcome (Tirado and Cotter, 2010). Some scientists documented that climate variability reduces the productivity of maize, wheat, rice, potatoes, and vegetables and endures to reduce really in the upcoming time period (Ignaciuk and Mason-D'Croz, 2014). It was documented in another study that variations in climate will possibly have a general important impact in decreasing the yield of cotton and sugarcane in Ethiopia (Bayrau et al., 2015).

Africa is the world's 10th major producer of livestock production and their products (MacDonald and Simon, 2011), which create around 10% of the African's foreign currency incomes (Pantuliano and Wekesa, 2008). Recurrent and extreme droughts have a significant influence on Ethiopia's livestock production because reduced rainfall cause shortage of presented water sources and decreases the production of rangeland and grassland. The major reason of livestock demises in Africa are lacks of food and water throughout drought (MacDonald and Simon, 2011). Highest temperatures also could affect the performance and metabolism of livestock, like reduction in consumption of food and a deficiency in productivity (Thornton et al., 2009).

Some scientists highlight, that "climate variation is a universal phenomenon" however people will be pretentious by its local effects. It is a local effect that is precarious in the climate variability dissertation since variation must be suitable to the confined circumstances which have established to fluctuate extensively through geographical areas with some regions gaining benefits whereas others have more vulnerability (Hein et al., 2009). The condition of different regions are given below.

West Africa

Climate variability effects in West Africa seem to usually reflection of what occurs in all other regions of Africa. Scientists commenced an extensive research covering the all regions of West Africa to comprehend the effects of climate variations on agriculture production. West Africa include countries like Burkina Faso, Gambia, Verde, Benin, Cape, Guinea Bissau, Niger, Togo, Mali, Liberia, Sierra Leone, Senegal, Cote D' Ivoire, Ghana and Nigeria. Generally, it was concluded from this study that climate variability poses an excessive danger to agriculture production dependent living beings in the West African states (Jalloh et al., 2013).

According to concepts of universal global warming tendencies, the study developed that growing temperatures would negatively impact the growth of specific crops like sorghum, whereas decreased precipitation is too estimated to deteriorate the situation (Jalloh et al., 2013). Scientists observed many factors which makes West African Agricultural productivity vulnerable to climate variation, from which one is rainfall. For instance, in Ghana, only four percent of potential land is underneath irrigation. Extreme poverty stages also subsidize to a general failure to endow into adaptation processes by farmers (Jalloh et al., 2013).

Southern Africa

Southern African region comprise countries like South Africa, Botswana, Zimbabwe, Mozambique, Malawi, Tanzania, Angola, Namibia, Lesotho and Swaziland. This region is usually proposed to become drier and hotter in the future decades. Additionally, it was already presented that patterns of rainfall would become volatile and unpredictable. Presently rainfall periods have present considerable cyphers of shortening, thus disturbing time periods of cropping (Mubaya et al., 2012). Other predictions involve high level of floods and droughts, decreased farming production and enhanced water scarcity (Shackelton and Shackelton, 2012). Even temperature of soil is also an important factor according to selection of plant for good agricultural production (Bağdatlı and Ballı, 2020). Additionally there is anticipation that wet season will be shortened and variations of rainfall patterns will be increased from one season to another season, and this will be extremely risky for agricultural yield (Mubaya et al., 2012).

The Sahel Region

This is one of the most vulnerable regions, which can be effected by climate variability. The Sahel region comprise nine countries which are situated near to the Sahara desert. These involve Burkina Faso, Guinea Bissau, Mali, Niger, Mauritania, Cape Verde, Chad, Gambia and Senegal. This region have low rainfall and high temperatures, highly dependence of local peoples on rain fed agriculture production, have high population and less adaptive ability (Mohamed, 2011; Hein et al., 2009). Scientists noticed that the effect of climate variability has mostly been undesirable in the Sahel region. They also said that more than 50 percent of the people in this region are working in the agricultural area, and agriculture subsidizes from 35 percent to 60 percent of the state economic outcome. Like other regions of Africa, agriculture in the Sahel region also suffered from many factors like the burden of increasing populations on existing land and declining soil fertility. It was also observed from 1960s that Precipitation also decline due to shortage of rainfall as in other regions of Africa, so more drought has been observed (Sissoko et al., 2011). Reduction in precipitation has serious implications for availability of water and livelihoods in the Sahel region including cropping and livestock raising (Mohamed, 2011).

REFERENCES

Afreen M., Ucak I. & Bagdatli M.C. 2022. The Analysis of Climate Variability on Aquaculture Production in Karachi of Pakistan, *International Journal of Engineering Technologies and Management Research (IJETMR)*, 9(8), 16-23. doi: 10.29121/ijetmr.v9.i8.2022.1210,

Arnell N.W., Van Vuuren D.P. & Isaac M. 2011. The implications of climate policy for the impacts of climate change on global water resources. *Global Environmental Change,* 21, 592–603.

Asseng S. et al. 2015. Rising temperatures reduce global wheat production. *Nature Climate Change,* 5, 143–147.

Bağdatlı M. C., Uçak I. & Elsheikh W. 2023. Impact of Global Warming on Aquaculture in Norway. *International Journal of Engineering Technologies and Management Research,* 10(3), 13–25. doi: 10.29121/ijetmr.v10.i3.2023.1307

Bagdatli M.C. & Arikan E.N. 2020. Evaluation of maximum and total open surface evaporation by using trend analysis method in Nigde province of Turkey. *International Journal of Geography and Regional Planning (IJGRP)*, 6(1), 138-145. doi: 10.5281/zenodo.3890231,

Bagdatli M.C. & Arslan O. 2019. Evaluation of the number of rainy days observed for long years due to global climate change in Nevşehir/Turkey. *Recent Research in Science and Technology Journal*, 11, 9-11.

Bagdatli M.C. & Arslan O. 2020. Trend Analysis of Precipitation Data Observed for Many Years (1970-2019) in Niğde Center and Ulukisla District of Turkey, *International Journal of Recent Development in Engineering and Technology (IJRDET)*, 9(7), 1-8.

Bağdatlı M.C. & Ballı Y. 2019. Evaluation with Trend Analysis of The Open Surface Evaporation in Observed for Many Years: The Case Study in Nevsehir Province of Turkey. *Recent Research in Science and Technology Journal*, 11, 15-23.

Bagdatli M.C. & Belliturk K. 2016. Negative effects of climate change in turkey. *Advance in Plants & Agriculture Research*, 3(2), 44–46. doi: 10.15406/apar.2016.03.00091.

Bagdatli M.C. & Can E. 2019. Analysis of Precipitation Data by Mann Kendall and Sperman's Rho Rank Correlation Statistical Approaches in Nevsehir Province of Turkey. *Recent Research in Science and Technology Journal*, (11), 24-31.

Bagdatli M.C. & Can E. 2020. Temperature Changes of Niğde Province in Turkey: Trend analysis of 50 years data. *International Journal of Ecology and Development Research*, 6(2), 62-69.

Bağdatli M.C., İstanbulluoğlu, A., Altürk B. & Arslan C. 2014. Evaluation of the change trend in long-year temperature data in terms of agricultural drought: The case of Çorlu. *Duzce University Journal of Science and Technology*, *2*(1), 100-107.

Bağdatlı, M. C. & Arıkan, E. N. 2020. Evaluation of monthly maximum, minimum and average temperature changes observed for many years in Nevsehir province of Turkey. *World Research Journal of Agricultural Sciences*, 7(2), 209-220.

Bağdatlı, M. C. & Ballı, Y. 2020a. The analysis of soil temperatures in different depths using spearman's rho and mann-kendall correlation tests: the case study of Nigde center in Turkey. *International Journal of Engineering technologies and Management research*, 7(5).

Bağdatlı, M. C. & Ballı, Y. 2020b. Soil Temperature changes (1970-2019) in ulukışla district in turkey by trend analysis methods. *International Journal of Plant Breeding and Crop science*, 7(2), 851-864.

Bagdatli, M. C., Arslan, O., Balli, Y. & Uguz, A. N. 2022. GIS modelling and evaluation of climate variability in kizilirmak watershed of turkey. *International Journal of Engineering technologies and Management research*, 9(5), 48-54.

Bağdatli, M. C., Bellitürk, K. & Jabbari, A. 2015. Possible effects on soil and water resources observed in Nevşehir Province in long annual temperature and rainfall changing. *Eurasian Journal of Forest Science*, 3(2), 19-27.

Baldos U. L. C. & Hertel T. W. 2014. Global food security in 2050: the role of agricultural productivity and climate change. *Australian Journal of Agricultural and Resource Economics*, 58, 554–570.

Barrios E., Valencia V., Jonsson M., Brauman A., Hairiah K., Mortimer P. E. & Okubo S. 2018. Contribution of Trees to the Conservation of Biodiversity and Ecosystem Services in Agricultural Landscapes. *International Journal of Biodiversity Science, Ecosystem Services and Management*, 14, 1–16. doi:10.1080/21513732.2017.1399167.

Barrios S., Ouattara B. & Strobl E. 2008. The impact of climatic change on agricultural production: Is it different for Africa? *Food Policy*, 33(4), 287–298. doi: 10.1016/j.foodpol.2008.01.003

Bayrau A., Assefa B. & Hagos A. 2015. Productivity and Welfare Impact of Climate Change in Sugarcane and Cotton Producing Regions of Ethiopia. EDRI Research Report 23. Addis Ababa: *Ethiopian Development Research Institute.*

Bommarco R., Vico G. & Hallin S. 2018. Exploiting Ecosystem Services in Agriculture for Increased Food Security. *Global Food Security*, 17, 57–63. doi:10.1016/j. gfs.2018.04.001.

Brown B., Nuberg, I. & Llewellyn, R. 2018. Constraints to the Utilisation of Conservation Agriculture in Africa as Perceived by Agricultural Extension Service Providers. Land Use Policy 73: 331–340. doi:10.1016/j. landusepol.2018.02.009.

Bwalya M. 2013. Comprehensive Africa Agriculture Development Programme (CAADP) to reduce food security emergencies in Africa, NEPAD Planning and Coordinatng Agency, Johannesburg.

Challinor A., Wheeler, T., Garforth, C., Craufurd, P. & Kassam A. 2007. Assessing the vulnerability of food crop systems in Africa to climate change. *Climate Change*, 83, 381–399.

Dube T., Moyo P., Ncube M. & Nyathi D. 2016. The impact of climate change on agro-ecological based livelihoods in Africa: *A review, Journal of Sustainable Development*, 9(1), 256-267.

Elsheikh W., Ilknur U., Bağdatlı M.C. & Mofid A. 2022a. Effect of Climate Change on Agricultural Production: A Case Study Khartoum State, Sudan, *Open Access Journal of Agrcultural Research*, 7(3), 000299.

Elsheikh W., Uçak I. & Bağdatlı M. C. 2022b. The Assessment of Global Warming on Fish Production in Red Sea Region of Sudan. *Eurasian Journal of Agricultural Research*, 6(2), 110-119.

Evangelista P., Nicholas P., Young N. & Burnett J. 2013. How Will Climate Change Spatially Affect Agriculture Production in Ethiopia? Case Studies of Important Cereal Crops, *Journal Climatic Change* 119, 855–873. doi:10.1007/s10584-013-0776-6.

FAO. 2007. Adaptation to Climate Change in Agriculture, Forestry and Fisheries: Perspective, Framework and Priorities; Food and Agriculture Organization of the United Nations (FAO): Rome, Italy,

FAO. 2014. Ethiopian Country Program Framework. Addis Ababa: FAO.

Funk C., Senay G., Asfaw A., Verdin J., Rowland J., Michaelson J., Eilerts G., Korecha D. & Choularton R. 2005. Recent Drought Tendencies in Ethiopia and Equatorial-Subtropical Eastern Africa. Washington DC: FEWS-NET.

Gebreegziabher Z., Jesper S., Mekonnen A. & Alemu A. 2011. Climate Change and the Ethiopian Economy: A Computable General Equilibrium Analysis. http://www.rff.org/files/sharepoint/WorkImages/Download/EfDDP-11-09.pdf]

Georg L. A. G., Requier A. F. & Fijen T. 2018. Complementarity and Synergisms among Ecosystem Services Supporting Crop Yield. *Global Food Security*, 17, 38–47. doi:10.1016/j.gfs.2018.03.006.

Hasegawa T. et al. 2014. Climate change impact and adaptation assessment on food consumption utilizing a new scenario framework. *Environmental Science and Technology*, 48, 438–445 .

Hein L., Metzger M. J. & Leemans R. 2009. The local impacts of climate change in the Ferlo, Western Sahel. *Climatic Change*, 93(3-4), 465–483. doi: 10.1007/s10584-008-9500-3

Hoffmann U. 2013. Agriculture: A Key Driver and a Major Victim of Global Warming. Geneva: United Nations Conference on Trade and Development.

Hope C. 2006. The marginal impact of CO_2 from PAGE2002: an integrated assessment model incorporating the IPCC's five reasons for concern. *Integrated Assessment Journal*, 6(1).

Ignaciuk A. & D. Mason-D'Croz. 2014. Modelling Adaptation to Climate Change in Agriculture. *OECD Food, Agriculture and Fisheries Papers*, 70, 58.7.

Intergovernmental Panel on Climate Change (IPCC), 2007. *Intergovernmental panel on climate change fourth assessment report*, Cambridge University Press, Cambridge, UK.

İstanbulluoğlu A., Bağdatlı M.C. & Arslan C. 2013. To evaluated with trend analysis of long-annual rainfall: Tekirdag-Corlu district application. *Journal of Tekirdag Agricultural Faculty*, 10 (2), 70-77.

Jalloh A., Nelson G. C., Thomas T. S., Zougmoré R. & Roy-Macauley H. 2013. West African agriculture and climate change: A comprehensive analysis. *IFPRI Research Monograph*. doi:10.2499/9780896292048

Liliana H. 2005. The food gaps: The impacts of climate change on food producton: A 2020 perspectve, Universal Ecological Fund, Alexandria, VA, USA.

Lobell D.B., Burke, M.B., Tebaldi, C., Mastrandrea M.D., Falcon W.P. & Naylor R.L. 2008. Prioritizing climate change adaptation needs for food security in 2030. *Science*, 319, 607–610.

Lotze-Campen, H. et al. 2014. Impacts of increased bioenergy demand on global food markets: an AgMIP economic model inter comparison. *Agricultural Economics Research*, 45, 103–116.

MacDonald, M. & J. Simon. 2011. Climate, Food Security, and Growth Ethiopia's Complex Relationship with Livestock. Policy Brief 3. New York, NY: Brighter Green Publisher.

Mohamed, A. Ben. 2011. Climate change risks in Sahelian Africa. *Regional Environmental Change*, 11(SUPPL. 1), 109–117. doi: 10.1007/s10113-010-0172-y

Mubaya, C. P., Njuki, J., Mutsvangwa, E. P., Mugabe, F. T. & Nanja, D. 2012. Climate variability and change or multiple stressors? Farmer perceptions regarding threats to livelihoods in Zimbabwe and Zambia. *Journal of Environmental Management*, 102, 9–17. doi: 10.1016/j.jenvman.2012.02.005

Nelson, G. C. et al. 2014. Climate change efects on agriculture: Economic responses to biophysical shocks. *Proceedings of National Academy of Sciences USA*, 111, 3274–3279.

Nhemachena C., Matchaya G., Nhlengethwa S. and Nhemachena C.R. 2016. Economic Aspects of Genetic Resources in Addressing Agricultural Productivity in the Context of Climate Change. In *Climate Change and Multi-Dimensional Sustainability in African Agriculture*; Springer International Publishing: New York, NY, USA, pp. 171–183.

OECD. 2014. Climate Change, Water and Agriculture: Towards Resilient Agricultural and Water Systems. doi: 10.1787/9789264209138-e.

Olmstead, S.M. 2014. Climate change adaptation and water resource management: A review of the literature. *Energy Economics,* 46, 500–509.

Pantuliano S. & Wekesa M. 2008. Improving Drought Response in Pastoral Regions of Ethiopia-somali and Afar Regions and Borena Zone in Oromiya Region. Ethopia: Addis Ababa.

Rosenzweig C., Elliott J., Deryng D., Ruane A.C., Müller C., Arneth A., Boote K.J., Folberth C. Glotter M. & Khabarov N. 2014. Assessing agricultural risks of climate change in the 21st century in a global gridded crop model intercomparison. *Proceedings of National Academy of Sciences USA*, 111, 3268–3273.

Shackleton S. E. & Shackleton C. M. 2012. Linking poverty, HIV/AIDS and climate change to human and ecosystem vulnerability in southern Africa: consequences for livelihoods and sustainable ecosystem management. *International Journal of Sustainable Development & World Ecology,* 19(3), 275–286. doi: 10.1080/13504509.2011.641039

Sissoko K., van Keulen H., Verhagen J., Tekken V. & Battaglini A. 2011. Agriculture, livelihoods and climate change in the West African Sahel. *Regional Environmental Change*, 11(SUPPL. 1), 119–125. doi: 10.1007/s10113-010-0164-y

Thornton P. K., Van de Steeg J., Notenbaert A. & Herrero M. 2009. The Impacts of Climate Change on Livestock and Livestock Systems in Developing Countries: A Review of What We Know and What We Need to Know.” *Agricultural Systems* 101, 113–127. doi:10.1016/j.agsy.2009.05.002.

Tirado R. & Cotter J. 2010. Ecological Farming: Drought-Resistant Agriculture. United Kingdom: Greenpeace Research Laboratories, University of Exeter.

Vogel C. 2005. Usable Science: An assessment of long-term seasonal forecasts among farmers in rural areas of South Africa, *South African Geographical Journal* 82(2), 107–116. Doi: 10.1080/03736245.2000.9713700

Von Lampe M. et al. 2014. Why do global long-term scenarios for agriculture difer? An overview of the AgMIP Global Economic Model Inter comparison. *Agricultural Economics Review,* 45, 3-20.

Wheeler T. & Von Braun J. 2013. Climate change impacts on global food security. *Science,* 341, 508-513.

Winfree R. & Kremen C. 2009. Are Ecosystem Services Stabilized by Differences among Species? A Test Using Crop Pollination.” *Proceedings of the Royal Society B,* 276, 229–237. doi:10.1098/rspb.2008.0709.

World Bank, 2016. *Arable land (hectares per person),* World Bank, viewed 28 November 2017, from http://data.worldbank.org/indicator/AG.LND.ARBL.HA.PC.

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Microbial Density and Diversity and Lead Loads in Selected Street-Hawked Foods in Akure Metropolis, Nigeria

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Abstract

Microbial density and diversity, as well as concentrations of lead, in selected street-hawked foods in Akure metropolis were investigated in this study. Street-vended/hawked foods offer numerous advantages to food security; nevertheless, the safety of street foods has been an issue of serious concern, mainly because of the poor sanitary standards and inadvertent contaminants. Seven selected food samples (zobo drink, rice and stew, African star apple, meat pie, cucumber, white pap, smoked fish) were purchased from vendors at three busy road intersections within the city. Metals were analyzed with atomic absorption spectrophotometry. The metals determined are Ca, Cu, Pb, Fe, Zn. The concentrations of the metals in mg/kg were in the range of Ca (24.50±0.10 to 32.00±0.10), Cu (0.75±0.03 to 1.12±0.01), Pb (0.05±0.01 to 0.30±0.01), Fe (0.19±0.01 to 0.31±0.01), and Zn (1.40±0.01 to 2.33±0.01). Lead values were well above permissible limits set by WHO, EU and USEPA, indicating a significant health risk. On the other hand, the presence of high concentration of calcium in the street hawked food indicate that the food is of good value. The microbial density of the street-hawked foods were as follows: zobo, rice and stew, African star apple and meat pie (52×10^2, 54×10^2, 2×10^2, 25×10^2 cfu/g), respectively. Only zobo drink had viable fungal counts (34×10^2 cfu/g) on Potato Dextrose Agar. The microbial isolates observed in this study were *Escherichia coli, Klebsiella pneumonia, Shigella spp, Staphylococcus aureus, Bacillus cereus*, in varied proportions which could be attributed to the utensils, exposure of food product environment and other related factors. Among the various microorganisms isolated from the street-hawked foods, *Escherichia coli, Staphylococcus aureus and Bacillus cereus* were quite prevalent. Some of the hawked street foods in Akure metropolis were of poor microbial quality, which is of public health concern.

Keywords: Street-hawked foods, Lead contamination, Microbial loads, Identified isolates, Hazards

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INTRODUCTION

Food has long been recognised as one of the basic needs of life due to its ability to provide nourishment, health and vitality to the consumer (Nwiyi and Elechi, 2022). Despite the importance attached to food, it is now common knowledge that there is increase in the outbreak of food borne illness as a result of both risky food preparation and eating behaviour. The issue of food security goes beyond increasing production, supply and consumption of food as the production, distribution and consumption capacities are being threatened by poor food safety and quality (Nwiyi and Elechi, 2022). Safe food is now seen as one of the fundamental human rights because of its potential to promote sound health and improve productivity for poverty alleviation as veritable platforms for sustainable development (Enujiugha, 2017). Lack of access to safe food leads to nutrition insecurity which in turn results in the double burden of malnutrition and food borne diseases.

Food safety can be seen as the level of assurance that the consumers repose on the food being eaten to provide the intended vital nourishment without any form of health hazard or risk (Enujiugha et al., 2023). The issue of food safety has generated global attention considering the reported cases of global, regional and national food borne disease outbreaks and huge numbers of food recalls which have eroded consumer confidence in the safety of food supply and agrifood production and trade in recent times (Enujiugha et al., 2023). The World Health Organisation reported estimate of 600 million people in the world falling sick after eating contaminated food as a result of which, 420 thousand die every year (WHO, 2015). This figure could be worse in the developing world if all the food borne outbreaks and deaths associated with food borne diseases are reported and properly documented.

In Nigeria, the majority of street food vendors are very poor and uneducated, with no knowledge of food hygiene or safety implications to human health. These vendors sell at relatively low prices thereby attracting the majority of low-income workers, shoppers, travelers on the highway and school children in an attempt to earn a living. The consumers seem to be more interested in aesthetics and quantity of serving sizes than in the safety and health implications of the street-hawked foods (Makanjuola and Enujiugha, 2015). Pepple (2017) identified poor cooking method and sanitary condition of cooking environment, while Ezirigwe (2018) observed personal hygiene of food handlers as potential sources of food borne diseases in Nigeria. Street foods are regarded as one of the potential sources of food borne illness because of their high susceptibility to microbial spoilage (Yammine and Karam, 2020) due to poor storage temperature and mal-handling practices that expose them to contamination and cross contamination (Kigigha et al., 2017).

With the global rise in foodborne diseases outbreak and with the increasing demand for safe food by respective governmental regulatory and monitoring agencies, coupled with the rising trend of rural-urban migration in developing countries of the sub-Saharan Africa, there is a need to evaluate the quality, safety, and keeping quality of street hawked foods in a typical urban neighbourhood such as Akure metropolis in Nigeria.

MATERIALS and METHODS

Sources of Materials

Cucumber, orange, pap, cooked rice, garden egg, zobo, meat pie and smoked fish were purchased from three (3) busy road intersections as well as Oba market all in Akure, Ondo state. All reagents used in the study were of analytical grade.

Mineral Determination

For each sampled food type, 1 g of sample was placed in a crucible and ashed in a muffle furnace at 550 ℃ for 5 h and transferred into a desiccator to cool. The ashed sample was used by dissolving it with a mixture of 1 mL nitric acid and 1 mL HCl and made up to 100 mL. This was used to analyze for Na, K, Ca, Cu, Fe, Zn and Pb.

The atomic absorption spectrophotometer Model-210 VGP (Buck Scientific, USA) was used to determine Ca, Cu, Fe, Zn and Pb in all the samples. The flame emission photometer (FES 902 Friedrich Ebert Stiftung) was used to measure the values of Na and K in all the samples.

Microbiological analysis

A 1-g quantity of each sample was aseptically weighed into 9 ml sterile water in a McCartney bottle and the content was shaken vigorously. Microbial count was estimated by the pour plate method (0.1 mL inoculum in 10-15 mL warm medium) using serial dilution technique. Subsequent decimal dilutions (10^{-2}, 10^{-3}, 10^{-4}, etc) were made from 1ml of solution of preceding concentration in 9 mL of diluent. Plates were inverted and incubated at 30 ˚C for 24 h in a Gallenkamp incubator. At the end of the incubation period, only plates showing between 30 and 300 colonies were counted. Colony counts were expressed as colony forming units (cfu) per gram of sample, and all analyses were carried out in triplicates with average values reported. Identification and characterization of the isolates were carried out using appropriate morphological and biochemical tests, as outlined in previous research works (Enujiugha et al., 2008; Enujiugha, 2009).

Statistical analysis

All the data collected, especially for the mineral analysis, were evaluated using analysis of variance (ANOVA) and analysed using SPSS statistical package (Version 17.0). Duncan’s New multiple range test was used to determine significant differences among the mean values for the samples at $p < 0.05$. All values were expressed as mean ± SD.

RESULTS and DISCUSSION

Concentrations of selected minerals in the food samples

Table 1 shows the results of the minerals composition of the selected street-hawked foods in Akure Metropolis. Heavy metals are considered as one of the most important constituents of food contamination from the environment due to their ability to persist, accumulate, and become toxic to living organisms through consumption along the food chain.

Lead was detected in all the street food samples, with all the street food samples seen to be higher than 0.01 mg/kg which is the maximum permissible limit set by WHO/FAO and also the maximum allowable concentration of 0.02 mg/kg by EU and 0.05 mg/kg limit set by USEPA. The high percentage of food samples which were in violation of the maximum permissible limits of Pb set by WHO, EU, and US EPA is a cause for public health concern considering the frequency of exposure (Enujiugha and Nwanna, 2004). The consumption of food contaminated with Pb is the major source of exposure to Pb in a general population. The values obtained in this study were higher than the Pb values reported by Bordajandi et al. (2014) in food samples from Huelva (Spain). It is known that Nigerian gasoline is commonly infused with Pb to prevent or reduce engine knocking; and this is released into the environment through vehicular emissions. It is therefore not surprising that foods hawked within major city intersections will have high Pb loads. High concentration burden of Pb in the body can cause irreversible brain damage (encephalopathy), anemia, coma, and death if not treated immediately (Vijayakumar, 2012). Long-term system exposure can cause damage to the kidneys and reproductive and immune system. Children are more vulnerable than adults to the toxic effects of Pb, and they also absorb Pb easily.

The calcium content ranged from 24.50±0.10 mg/100g to 32.00±0.10 mg/100g for smoked fish and African star apple. Calcium helps in the regulation of muscle contractions and transmission of nerve impulses as well as bone and teeth development (Adelekan et al., 2013). The increases in the content of the minerals recorded in all the samples could therefore be of nutritional advantage to consumers of the products. Ca is crucial in promoting the deposition of hydroxyapatite in bone and serves the mechanical roles of strengthening bones and teeth, it supports the functions of excitable tissues, including nerves and heart muscles, as well as blood clotting (Aspray, 2017)

Copper is an essential metal and serves as anti-oxidant and help the body to remove free radicals, prevent cell structure damage (Salama and Radwan, 2005). It also plays an important role in bone formation and skeletal mineralization (Mariam et al., 2005). The concentration of Cu in all the samples ranged between 0.75±0.03 to 1.16±0.01 mg/kg with meat pie having the highest concentration and cucumber having the least concentration. The limit for Cu in food is 10 mg kg^{-1} (European Commission, 2006). The results from this study is below the standard limit for Cu. The values of Cu reported in the present study were lower than the values reported in the literature for snacks samples (Cabrera et al., 2003; Salaman and Radwan, 2005). However, similar Cu levels have been recorded in confectionaries and other foods; for example, Ojo and Enujiugha (2018) reported high Cu levels for both whole maize ogi and the product from maize co-fermented with ground bean (*Kerstingiella geocarpa*). Iron is a mineral essential for life and for our diets (Enujiugha and Olagundoye, 2001). Results of Fe concentrations for all analysed street food samples are in the ranges of 0.19±0.01 mg kg^{-1} to 0.31±0.01 mg kg^{-1}. The maximum level of Fe was observed in white pap while the minimum level was observed in meat pie. These food items are potential sources of Fe for both children and adults. Deficiency of Fe in the body could result into anaemia. It is known that adequate iron in a diet is very important for decreasing the incidence of anaemia. Iron deficiency occurs when the demand for Fe is high, for example, in growth, high menstrual loss, and pregnancy; and the intake is quantitatively inadequate or contains elements that render the iron unavailable for absorption (Ijarotimi and Enujiugha, 2008).

Also, Fe is an essential nutrient supporting oxygen binding and transport, it is necessary for DNA synthesis and cellular proliferation. Due to these key roles, deficiency of Fe is manifested as anaemia, leading to reduced work capacity, impaired mental function, and lowered immunity. However, iron loading due to primary or secondary hemochromatosis can produce liver damage, leading to fibrosis, cirrhosis, and an increased risk of hepatic cancer (Wessling-Resnick, 2017).

The mean concentrations of Zn in the analyzed samples are in the range of 1.40 ±0.01 to 2.33±0.01 mg kg^{-1}. The highest mean level of Zn was observed in Zobo while the lowest mean level of Zn was observed in African star apple. Stadlmayr et al. (2012) reported mean Zn concentration in groundnut paste as 0.42 mg kg^{-1}. Sanusi et al. (2017) reported mean Zn concentration ranging from 6.8 to 15.3 mg kg^{-1} in popcorn and some other cereal-based snacks. Zn has been established as essential for health and nutrition especially in growth enhancement and enzyme-substrate interaction respectively.

Table 1: Composition of selected minerals in the street-hawked foods in Akure Metropolis (mg/100g)

Samples/Elements	Ca	Cu	Fe	Pb	Zn
A	29.53±0.10^{c}	1.12±0.01^{b}	0.26±0.01^{c}	0.05±0.01^{c}	2.33±0.01^{a}
B	26.50±0.01^{e}	1.09±0.01^{c}	0.28±0.01^{b}	0.07±0.01b	1.64±0.01^{f}
C	32.00±0.10^{a}	1.05±0.01^{d}	0.20±0.01^{e}	0.10±0.01^{a}	1.40±0.01^{g}
D	25.00±0.05^{f}	1.16±0.01^{a}	0.31±0.01^{a}	0.05±0.01^{c}	2.03±0.01^{c}
E	27.00±0.05^{d}	0.75±0.03^{g}	0.26±0.02^{c}	0.30±0.01^{d}	2.16±0.01^{b}
F	30.00±0.10^{b}	0.84±0.01^{f}	0.19±0.01^{f}	0.05±0.01^{c}	1.95±0.01^{d}
G	24.50±0.10^{g}	1.03±0.01^{e}	0.21±0.01^{d}	0.07±0.01^{b}	1.75±0.02^{e}

Mean ± standard deviation. Values with the same superscript alphabet in the same row is not significantly different at p>0.05, A: Zobo Drink ; B: Rice and stew; C: African star apple; D: Meat pie; E: Cucumber; F: White pap; G: Smoked fish

Microbial counts and distribution in the street food samples

The results of the microbial analysis of the street hawked food in Akure metropolis are presented in Tables 2 and 3. The microbial result of the street hawked food samples revealed varying degree of microbial contamination with some samples showing acceptable level of microbial load of < 10^4 cfu/g. The total viable count (TVC) is an indicator of quality, not safety, and cannot directly contribute towards a safety assessment of food but can be used as part of a general quality assessment including that of extended shelf-life of foods. Presence of bacteria in street hawked food in this study could pose health risk to the consumers. Poor food preparation handling, water, exposure to environment, inadequate washing of hands and utensils may have contributed to the presence of the various species of microorganism.

Microbial criteria regulation varies across countries. ICMSF (2017) Considers TVC in the range of 0-10^3 cfu/g, 10^4-10^5 cfu/g and >10^6 cfu/g as acceptable, marginally acceptable (tolerable), or unacceptable, respectively. The results of the microbial analysis from the TVC of the street hawked food were significantly visible in the microbial load of Zobo, (52 x 10^2 cfu/g), rice and stew (54 x 10^2 cfu/g), African star apple (2 x 10^2 cfu/g) and meat pie (25 x 10^2 cfu/g) respectively. The results are between the acceptable limit for street hawked food. This may be attributed to their low water content which reduces microbial population. On the other hand, rice and stew and zobo samples which had the highest water content were the most contaminated as they favour conditions for microbial growth. Cucumber, white pap and smoke fish were observed to be free of microbial contaminant. Conversely, the zobo drink showed the microbial load of (34 x 10^2 cfu/g) on Potato Dextrose Agar.

The morphological and biochemical characterization of the raw milk sample showed varied potential pathogens which can initiate food poisoning when present in high dose. The organisms were*; Escherichia coli, Klebsiella pneumonia, Shigella spp, Staphylococcus aureus, Bacillus cereus,* in varied proportion which could be attributed to the utensils, exposure of food product environment and other related factors (Downes and Ito, 2011).

Also, organisms isolated in this study might have been introduced into these foods from feacally polluted water used for washing utensils (e.g. knives, trays, and pans), wrapping materials and the exposure of these products to low temperature (Buchanan and Gibbons, 2014). It may also be as a result of the failure of food handlers to observe basic sanitary rules (Daniyan and Ajibo, 2011)

It may also be as a result of the failure of food handlers to observe basic sanitary rules (Buchanan and Gibbons, 2014). Contamination of the food samples from this agent may have resulted from talking and tasting during food preparation as well as through sharing of cutleries. Its presence also indicates careless handling of food after cooking.

Among the various microorganisms isolated from the street hawked food, *Escherichia coli*, *Staphylococcus aureus* and *Bacillus cereus* are predominating. Other bacterial species such as *Klebsiella pneumonia, Shigella spp,* were isolated. However, a study by Ezeh et al. (2017) isolated high percentage of *Escherichia coli*, while *Bacillus cereus* was the least for meat pie samples sold within Ochanja Main Market. The Zobo, rice and stew, African star apple and meat-pie, likewise the white pap cucumber and smoke fish samples were considered fit for human consumption since the distributions of the bacteria isolates were below standard threshold limit as found in this study.

Besides the bacterial species, species of fungi such *Saccharomyces cerevisiae* of food spoilage significant were equally isolated. Other researchers (Ezeh et al., 2017: Kidigha et al., 2017: Obande et al., 2017) isolated similar micro-organisms on meat pies and other meat products. The presence of these microbial isolates in the street hawked food and meat pies are due to various factors such as their opportunistic nature and ability to thrive under harsh environment (Ezeh et al., 2017), use of dirty processing equipment/materials, contaminated water, poor hygiene and food safety practices of the food processors. Most of these isolates are both medical and public health significant due to their pathogenic nature. This agrees with Madueke et al (2014) who reported that laboratory analysis of samples of certain hawked food had shown high levels of coliform and pathogenic bacteria to include *Salmonella sp, Staphylococcus aureus, Clostridium perfringens,* and *Vibrio cholera.*

Bacillus species are environmental contaminants found in the air, water and withstanding harsh weather condition thereby contaminating "vended snacks as they are vending activities take place in busy-crowded environment" (Ike et al., 2015). Being mesophilic bacteria, Bacillus species produce heat resistant endospores which on injection produces heat labile toxic that causes diarrheal illness accompanied with abdominal pain. The most favourable factor that promote the growth of bacillus and subsequent food borne infection and intoxication is wrong hot processing and holding temperatures of prepared food items. Meat pies fillings are minimally processed with the internal temperature not reaching the recommended core temperature of 145 ^{o}F and the street vended/hawked meat-pies are without any form of hot holding device that could maintain the holding temperature of 140 ^{o}F of the products. This keeps the meat pies within the "temperature danger zone" of 40 ^{o}F to 45 ^{o}F leading to proliferation of *Bacillus* and other co opportunistic bacteria.

Bacillus cereus is normally associated with rice, its presence in the rice and stew may be due to the fact that a spore former and the spores can withstand high temperature during frying of foods. *Bacillus* spp has the ability to form spores which are heat resistant. Achinewhu and Amadi (2016) reported the presence of B. cereus in some street foods in Port Harcourt.

Staphylococcus exists as part of normal skin flora of animals and humans and their presence in all the street hawked food samples suggest poor hygienic practices of both the processors and vendors such as the use of dirty hands, clothing and the practices of mouth blowing of air into packaging materials in an attempt to open them (Ezeh. et al., 2017). Staphylococcus bacteria in foods are considered worrisome as they are known to tolerate high concentration of sodium chloride and secretion of thermal stable enterotoxins which causes diarrhea and vomiting on ingestion (Aleruchi et al., 2016)

Equally, *E. coli* is a normal intestinal micro flora with the enteropathogenic strains implicated for causing travelers diarrheal and hemorrhagic colitis (Aleruchi et al., 2016). Although, the percentage of *E. coli* in zobo. Rice and stew and smoke fish samples in this study was not significant, its presence shows serious contamination by human or animal faecal matter from water sources utilized during the preparation, sorting and handling.

Table 2: Bacterial and fungal counts the samples (CFU/g)

Samples	Bacterial counts (CFU/g)	Fungal counts (CFU/g)
A	52×10^2	34×10^2
B	54×10^2	0
C	2×10^2	0
D	25×10^2	0
E	6×10^2	0
F	0	0
G	1×10^2	0

Mean ± standard deviation. Values with the same superscript alphabet in the same row is not significantly different at p>0.05, A: Zobo; B: Cooked rice with stew; C: African star apple; D: Meat Pie; E: Cucumber; F: white Pap; G: Smoked Fish

Table 3. Bacterial and Fungal Isolates

S/N	SAMPLE NO.	BACTERIAL ISOLATES	FUNGI ISOLATES
1	A	*Escherichia coli, Klebsiella pneumonia, Shigella spp, Staphylococcus aureus,*	*Saccharomyces cerevisiae*
2	B	*Escherichia coli, Staphylococcus aureus*	
3	C	*Bacillus cereus, Staphylococcus aureus*	
4	D	*Bacillus cereus, Staphylococcus aureus*	
5	E	*Bacillus cereus, Staphylococcus aureus, Escherichia coli*	
6	F		
7	G	*Escherichia coli, Bacillus cereus, Staphylococcus aureus*	

A: Zobo; B: Rice with stew; C: African star apple; D: Meat Pie; E: Cucumber; F: white Pap; G: Smoked Fish

CONCLUSION

There is no doubt that street food trade is very important to the socio-economy of developing countries. However, informal nature of the trade gives room for unwholesome activities which could pose serious hazards to the health and safety of the practitioners along the chain. The results revealed that the street foods contained lead in levels higher than the WHO permissible concentration, and this presents a real hazard to the consumers. This study also revealed the poor sanitation among street foods hawkers especially as regards feacal contamination of the foods, as well as the high loads of pathogens encountered. Proper management of the trade by all the stakeholders (farmers, vendors, consumers, governments, food and health professionals in academics and development partners) would ensure safe practices and engender safer and healthier society.

REFERENCES

Achinewhu S.C. & Amadi E.N. 1996. Bacterial Flora of Some Street Foods in Port Harcourt, Nigeria, *Niger Delta Biology*, 1, 59-61.

Adelekan A.O., Alamu A.E., Arisa N.U., Adebayo Y.O. & Dosa A.S. 2013. Nutritional, microbiological and sensory characteristics of malted soy-kunu zaki: an improved traditional beverage, *Advances in Microbiology*, 3, 389–397.

Aleruchi C., Etim L.B., Obande G.A., Asikong B.E. & Bashir Eya Sani B.E. 2016. Bacteriological Quality of Fresh Raw Beef and Chevon Retailed in Lafia Metropolis, Nigeria, *Journal of Microbiology Research,* 6(2), 29-34. doi: 10.5923/j.microbiology.20160602.01

Aspray T.J. 2017. Calcium: Basic Nutritional Aspects. In: *Molecular, Genetic, and Nutritional Aspects of Major and Trace Minerals*, J. F. Collins (ed.), Academic Press publications ISBN: 978-0-12-802168-2

Bordajandi L.R., Gomez G. & Abad E. 2014. Survey of persistent organochlorine contaminants (PCBs, PCDD/Fs, and PAHs), heavy metals (Cu, Cd, Zn, Pb, and Hg), and arsenic in food samples from Huelva (Spain): levels and health implications, *Journal of Agricultural and Food Chemistry*, 52(4), 992–1001.

Buchanan R.E. & Gibbons M.E. 2014. *Bergeys Manual of Determinative Bacteriology*, 8th edition, Williams and Wilkins, Baltimore, 305–318

Cabrera C., Lloris F., Gimenez R., Ollalla M. & Lopez M.C. 2003. Mineral content in legumes and nuts; contribution to Spanish, dietary intake, *Science of the Total Environment*, 308, 1–14.

Daniyan S.Y. & Ajibo C Q. 2011. Microbiological Examination of sliced fruits sold in Minna Metropolis, *International Research Journal of Pharmacy*, 2 (7), 124 -129.

Downes F.P. & Ito K. 2011. *Compendium of Methods for Microbiological Examination of Foods*, American Public Health Association, Washington, 4th ed., pp. 69-80.

Enujiugha V.N. 2009. Major fermentative organisms in some Nigerian soup condiments, *Pakistan Journal of Nutrition*, 8(3), 270-283.

Enujiugha V.N. 2017. Improving agricultural productivity through increased local biodiversity exploitation and food composition database management, *Journal of Biodiversity, Bioprospecting and Development*, 4(1), 162. doi:10.4172/2376-0214.1000162.

Enujiugha V.N., Adeyemo M.B. & Adisa A.M. 2023. Nutritional and safety implications of consuming melon seeds and impacts on international trade: A review, *Food and Humanity* (accepted).

Enujiugha V.N., Akanbi C.T. & Adeniran H.A. 2008. Evaluation of starters for the fermentation of African oil bean (*Pentaclethra macrophylla* Benth) seeds, *Nutrition and Food Science*, 38(5), 451-457.

Enujiugha V.N. & Nwanna L.C. 2004. Aquatic oil pollution impact indicators, *Journal of Applied Science and Environmental Management*, 8(2), 71-75.

Enujiugha V.N. & Olagundoye T.V. 2001. Comparative nutritional characteristics of raw, fermented and roasted African oil bean (*Pentaclethra macrophylla* Benth) seeds, *La Rivista Italiana delle Sostanze Grasse*, 78(4), 247-250.

Ezeh E., Okeke O., Ozuah A.C. & Agbanelo D.C. 2017. Bacteriological Assessment of Meat Pie Sold at Ochanja Market Onitsha, Anambra State, *International Journal of Environment, Agriculture and Biotechnology* (IJEAB), 2(2), doi: 10.22161/ijeab/2.2.26

Ezirigwe J. 2018. Much ado about food safety regulation in Nigeria, *The Journal of Sustainable Development Law and Policy*, 9(1), 109-132. doi: 10.4314/jsdlp.v9i1.6

ICMSF 2017. *Microorganisms in Foods 5 –Characteristics of Microbial Pathogens*, 1st ed. International Commission on Microbiological Specification for Foods. Blackie Academic & Professional, London, UK.

Ijarotimi O.S. & Enujiugha V.N. 2008. Child nutrition, growth and development in Africa. In: *Child Nutrition Physiology*, L.T. Overton & M.R. Ewente (eds.), NOVA Science Publishers Inc., New York, USA, pp. 257-280.

Ike C.C., Emeka-Ike P.C., Nwokorie C.C. & Anochie C.C. 2015. Microbiological Quality Evaluation of Locally Prepared Snacks Sold in Aba Metropolis, Abia State, Nigeria, *International Journal of Scientific Engineering and Applied Science* (IJSEAS), 1(7)

Kigigha L.T., Berezi J. & Izah S.C. 2017. Bacteriological Quality Assessment of Meat Pie Sold in Yenagoa Metropolis, Nigeria, *EC Nutrition*, 6(6), 189-195.

Madueke S.N., Awe S. & Jonah A.I. 2014. Microbial Analysis of Street Foods along Lokoja - Abuja Expressway, Lokoja, *American Journal of Research Communication*, 2(1).

Makanjuola S.A. & Enujiugha V.N. 2015. How consumers estimate the size and appeal of flexible packaging, *Food Quality and Preference,* 39, 236-240.

Nwiyi I. & Elechı J.O.G. 2022. Evaluation of Food Safety and Nutritional Quality of Indigenous Beverages Vended in Informal Market of Nasarawa State, North Central, Nigeria, *Eurasian Journal of Food Science and Technology*, 6(2), 100-112.

Obande G.A., Umeh E.U., Azua E.T., Aleruchi C.I., Adikwu P. 2014. Public Health Practices at Meat Pie Retail Points in Makurdi, Benue State and its Potential Effect on Consumer's Health. *African Journal of Clinical and Experimental Microbiology*, 18(1), 354. doi: 10.4314/ajcem.v18i1.5

Ojo D.O. & Enujiugha V.N. 2018. Comparative evaluation of ungerminated and germinated co-fermented instant 'ogi' from blends of maize (*Zea mays*) and ground bean (*Kerstingiella geocarpa*), *Journal of Nutritional Health and Food Engineering*, 8(1), 68-73. doi: 10.15406/jnhfe.2018.08.00258

Pepple N. 2017. Environment and Food Poisoning: Food Safety Knowledge and Practice among Food Vendors in Garki, Abuja – Nigeria, *Journal of Health Education Research and Development*, 5, 217. doi: 10.4172/2380-5439.1000217

Salama A.K. & Radwan R.M. 2005. Heavy metals (Cd, Pb) and trace elements (Cu, Zn) contents in some foodstuffs from the Egyptian market, *Emirate Journal of Agricultural Science*, 17(1), 34–42.

Sanusi R.A, Akinyele I.O., Ene-Obong H.N. & Enujiugha V.N. (eds.). 2017. Nigerian Food Composition Table (Harmonized edition), *Nigeria Foods Database Network*, University of Ibadan, Nigeria (ISBN 978-978-52841-7-1), p.85

Stadlmayr B., Charrondiere U.R., Enujiugha V.N., Bayili R.G., Fagbohoun E.G., Samb B., Addy P., Barikmo I., Ouattara F., Oshaug A., Akinyele I., Annor G.A., Bomfeh K., Ene-Obong H., Smith I.F., Thiam I. & Burlingame B. 2012. West African Food Composition Table, FAO Publications, Rome (ISBN 978-92-5-007207-4), p.150

Vijayakumar S., Sasikala M. & Ramesh R. 2012. Lead poisoning - an overview, *International Journal of Pharmacology and Toxicology*, 2(2), 70–82.

Wessling-Resnick M. 2017. Iron: Basic Nutritional Aspects. In: *Molecular, Genetic, and Nutritional Aspects of Major and Trace Minerals* (J.F. Collins, ed.), Academic Press publications ISBN: 978-0-12-802168-2

WHO 2015. Estimates of the Global Burden of Foodborne Diseases, *Foodborne Diseases Burden Epidemiology. Reference Group 2007–2015*, World Health Organization, Geneva.

Yammine J. & Karam L. 2020. Microbiological quality and safety of retail chicken and beef products in Lebanon, *Journal of Food Quality and Hazards Control*, 7, 60-66.

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Determination of Perceptions and Purchasing Factors of Turkish Consumers on Essential Oils

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Abstract

The aim of the present study is to determine the factors affecting the purchasing perceptions and motivations of consumers living in different regions of Türkiye on essential oils. A questionnaire including 16 questions applied to 603 volunteer participants to understand which factors affecting purchasing decisions of consumers. While 66% of the participants stated that they had purchased essential oils at least once, 44% stated that they had never purchased them. It was determined that the participants mostly used black cumin oil for medical purposes in asthma and respiratory disorders, and coconut and argan oil were mostly used for cosmetic purposes in hair and skin care. Age and monthly income level of the participants are effective on both reasons for use and purchasing motivations of essential oils. Remarkably, it was determined that participants with high levels of education mostly received advice on the uses of essential oils from various sources such as the internet and television. In conclusion, the findings of this study provide clear explanations regarding the perception and purchasing motivations of consumers with different demographic characteristics regarding essential oils.

Keywords: Essential oils, Consumption, Purchasing decision, Consumers, Survey

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INTRODUCTION

Determination of consumer perceptions and preferences are the key factors to understanding buying behaviors and motivations hence; these factors determine to success of marketing. Generally, socio-demographic factors play an important role on consumers purchasing behaviors. In addition, product features such as brand, packaging, label, certifications, price and quality are effective on consumers' purchasing decisions. Increasing the world population, technological developments and rapid living conditions increased healthy-life concerns and changed consumers purchasing motivations and preferences (Aday and Yener, 2014; Goh and Ng, 2021; Samiee et al., 2005). Nowadays, about healthy life, balanced nutrition and protection against disease people are easy and quick access to information. In this context, consumers are increasingly interested in complementary and/or traditional medicine. This interest also increases consumers' interest in natural/green and organic/ecologic products day by day, and this is defined as "return to natural"(Goh and Ng, 2021; Samiee et al., 2005).

Türkiye consists of seven regions that different socio-cultural structure in terms of lifestyle, eating habits, purchasing motivations and preferences. Türkiye linked the European and Asian continents, so it is interacted with both continental culture. These cultural interactions are effective on the lifestyle of Turkish people. Like many countries in the world, Türkiye has a historical knowledge about complementary medicine that has been passed down from generation to generation. The critical questions are “where consumers get this information” and “whether the information is reliable.” Essential oils (EOs) have an important place in complementary/traditional medicine in many countries due to its phytochemical, aromatic and bioactive compounds. Therefore, EOs is used aromatherapy and phytotherapy for cosmetics, food supplement and nutraceutical purposes (Aburjai and Natsheh, 2003; Bivins, 2010; Ribeiro et al., 2015).

Paracelsus von Hohenheim used the term of essential oils for the first time in the 16th century (Dhifi et al., 2016; Edris, 2007). In addition, there are approximately 3000 kinds of essential oils obtained from 2000 aromatic plants in the world and 300 of them have commercial importance. EO production in the world ranges between 40,000 and 60,000 tons per year and the market value is about 700 million U.S. (Raut and Karuppayil, 2014). On the other hand, total EO production of the world is approximately 100,000-150,000 tonnes according to a projection (Chakravarty et al., 2021). In literature there is very limited study about consumers’ behaviors on essential oil consumption, though EO production and consumption is increasing all over the world. Therefore, understanding of the consumers’ perceptions and purchasing motivations on the essential oils play a key role for marketing strategies of the essential oils and related industries.

The main aim of present study is to determine and evaluate perceptions, purchasing factors and motivations of Turkish consumers on essential oils consumption with regard to diseases and socio-demographic data.

MATERIAL and METHOD

Questionnaire and participants

In this study, a 16-questionnaire was applied to 603 volunteer participants who were living different parts of Türkiye. The questions were selected sensitively for the purpose and the questionnaire was kept short so that the participants were not bored. Questions 1 to 5 are related to the demographic characteristics of the participants, while question 6 is related to "purchase or not." Therefore, participants who bought essential oil at least once in their lives answered all of the questions in the survey.

Consequently, 304 participants were completely answered all questions and completed the survey. The other questions were prepared as multiple choice, which was related understanding consumer purchasing motivations, preferences and perceptions on the essential oils. Survey prepared Turkish then translated to English and it was applied with online form due to the Covid-19 outbreak. In the questionnaire, there were absolutely no questions regarding the identity information of the consumers and the participants informed that there were no "right and wrong answer" in the questions. The questionnaire and frequencies are given in Table 1.

Statistical Evaluation

The data obtained from the survey was evaluated descriptive statistics, cross tabs and correspondence analysis by using SPSS (SPSS Inc., Chicago, IL, USA). Correspondence analysis was used to explain the relationship between demographic data and multiple-choice questions and understanding consumers' purchasing motivation and, preferences. The categorical results were expressed graphically on multidimensional plot. In these plots, closely related categories were closer to each other.

RESULTS and DISCUSSION

Türkiye has 83 million total population in 2019 and 26.29% people were under 18, 12.76% - 18-25, 15.26% - 26-35, 14.99% - 36-45, 12.06% - 46-55 and 18.63% were over 55 age. Proportion of females in the population is 50.17% while males are 49.83%. The percentage of married and single peoples are 62.85 and 37.15%, respectively (TSI, 2019).

The demographic features of the respondents are presented in Table 1. 44.20% of respondents were 18-25, 29.20% of 26-35, 18.5% of 36-45, 5.5% of 46-55 and 2.5% of 55 and over ages. 40.60% of respondents were married and 59.4% were single while 40.60% were male and 59.4% were female. The majority of the participants were university graduates (65.1%) while high school, MSc, primary and PhD graduates were 18.8%, 8.2%, 4.1% and 3.8%, respectively. Additionally, the rate of respondents was 0-1500 ₺ - 31.8%, 1501-2500 ₺ – 13.4%, 2501-3500 ₺ – 19.4%, 3501-5000 ₺ – 16.6%, 5001 ₺ and over -18.8% according to monthly income level.

The data mentioned above almost reflects Türkiye’s demographic data. In addition, a similar data distribution was observed in the study reported by Cadar et al. (2021). 19.5% of the participants were under 25 years old, 26% between 25 and 34 years old, 26.5% between 35 and 44 years old, 15.3% between 45 and 54 years old and 12.7% of 55 and over years old according to study. Researchers reported that ratio of the high school graduate and university graduate respondents were 40.2 and 32.9%, respectively. Additionally, in the same study reported that low income participants (1000-4000 lei) were predominant. Another study performed by Korkmaz et al. (2011) reported that gender distribution of the participants were 53.9% of men and 46.1% women. The distribution of the demographic data reported by previous research is aligned with our data.

66% of participants purchased essential oils “at least once” according to Table 1 while 44% of participants “never purchased.” The participants expressed the reasons for not purchasing as "I have no information about it" (22.8%), "I don't think it's useful" (8.2%), "I think it's expensive" (2.0%) and "I don't believe they are pure and original" (1.0%). The respondents purchasing essential oil only from herbalists, markets, internet, and pharmacies were 54.2%, 10.3%, 11.1% and 3.7%, respectively. In addition, considering multiple responses, herbalists, markets, and internet were 63.9%, 21.1% and 22.3%, respectively.

These results proved that consumers firstly preferred herbalists when they purchased essential oils. A previous study reported that 288 of 400 participants purchased aromatic plants from herbalists while the others purchased from supermarkets (Güney, 2019). Literature data are close similar to our findings. Nevertheless, only 26.2% of respondents believed that their purchases were safe and pure while 30.7% did not believe, and 43.1% were in doubt. One of the remarkable results was the consumers bought the essential oils (67.8%) although the vast majority (58.6%) did not believe it pure and reliable.

The main factors affecting purchasing motivations of consumers on essential oils were priced, packs, trademark and certificates. Considering the multiple answers of the respondents, price, pack, trademark and certificate were 32.5, 14.2, 44, and 57.2%, respectively. These results clearly demonstrated that consumers primarily considering to product certification and secondary product brands when making decisions to purchase EOs. Many research on many products was shown that consumers purchasing decision was mostly depending on their monthly income level (Cadar et al., 2021; Güney, 2019; Nandi et al., 2017; Singh and Verma, 2017). Moreover, product price was third important buying factors.

Similar results reported by Shamri et al. (2021) for local brand of food product. Researchers indicated that halal logo was the first choice and product price was the second choice considered by consumers when buying food products. Frequency of use of EOs of the respondents were 5.3% every day, 27.3% several times a week, 30.2% several times a month and 37.3% several times a year. These results showed that EOs was used when needed rather than daily usage. Participants indicated that they used EOs as 30.2% cosmetics/beauty, 38.2% medicinal/health purposes and 4% food supplements. According to the multiple-choice data obtained from the participants, their intended use was determined as 51.5% cosmetic / beauty, 61.6% medical / health and 15.5% food supplements.

It is seen that the vast majority of the participants get information about the use of essential oils from the internet. Other sources of information are TV, medical advice, magazines and newspapers, respectively. In a study reported that 44% of participants used internet gain health information in European countries (Andreassen et al., 2007).

Considering the single choice data obtained from respondents, the mostly preferred EOs were black cumin, sweet almond, St. John's Wort, thyme, lavender, coconut and argan oils, respectively. According to multiple choices data, 53%- black cumin, 38%- argan, 34.5%- sweet almond, 33.7%- St. John's Wort, 32%- coconut, 26.7%- lavender, 19.7%- thyme, 19.5%- turpentine, 17.7%- mint, 17%- tea tree, 16.5%- castor, 12.8%- rose and 11.3%- rosemary oil were preferred by respondents. Following these oils mentioned above, jojoba, citrus, apricot kernels, laurel, basil, clove, eucalyptus and grape seed oils were preferred less than 10%.

When asked about the reasons for using the oils listed above, the most common answers were skin and hair care, stress and anxiety, rheumatic disease, diet, respiratory disorders, anti-aging, varicosis and migraine, respectively. For these disorders and/or diseases, respondents indicated that used EOs as a cream/lotion (60%), food supplements (8.7%) and aromatherapy (4.7%). The remarkable result is 84.7% of respondents believe that herbal solutions or alternative/complementary medicine is useful.

Relationship between demographic data and uses essential oils

Figure 1a, b and c showed relations between respondents' age and purchasing motivations of essential oils. As seen from Figure 1a, participants with 18-25 age specified that they purchased sweet almond, mint and thyme oils, while 26-35 group of age turpentine and St. John's Wort oils and 36-45 group of age castor, lavender and black cumin oils. Additionally, participants aged with 18-25 stated that they mostly used EO for hair and skin care purposes while 26-35 age against the stress and anxiety and 36-45 age anti-aging agent and weight loss (Figure 1b).

It was determined that participants with 18-35 age retrieval information about essential oils and their medicinal activities from internet while participants aged 36-55 were getting information on television. Contrary to the participants with 18-35 and 36-55 age, participants with 55 and over age stated that they were received medical advice from professionals (Figure 1c). Wald et al. (2007) reported internet use for health information is rapidly increasing. In the same study researchers indicated that the number of internet users for getting knowledge about health was 54 million in 1998 while 117 million in 2005 in the U.S. The 80% of adult internet users were used web for their health concerns and getting information about it in the U.S. (Wald et al., 2007).

Education was one of the most important and effective factors on information resources about essential oils and their medical effects. Similarly, education has a key role in influencing consumer attitude and behavior was reported by Mancini et al., (2017). There were remarkable results between education level and information resources. Results showed that primary school graduate using medical advice for getting information about EO while higher graduates using TV and internet (Figure 1d). In addition, PhD graduates were used essential oils as food supplements, high school graduates for medicinal purposes and, university and master degree for cosmetic purposes (Figure 1e).

One of the previous studies reported that relationship among the internet use for health and being youth, being female, higher education, white collar, no paid job long-term illness and disabilities (Andreassen et al., 2007). In another study reported that relationship between those who did not use the internet for health purposes and participants who had lower education levels, had more children, were male, and visited less frequently a general practitioner (Wangberg et al., 2008).

The effect of the income levels on purchasing factors, using purposes and disorders are shown in Figure 1f, g and h, respectively. The most important purchasing factor for the participants with 0-1500, 2501-5000 and over 5000₺ monthly income groups were "price," "trademark" and certificates, respectively (Figure 1f). On the other hand, participant with 0-1500₺ monthly income was used EO as cosmetic purposes while 3501-5000₺ and over 5000₺ monthly income levels used EO as medicinal purposes (Figure 1g). Participants with the lowest and highest income levels stated that they preferred to use EO for asthma and respiratory disorders and hair care, respectively (Figure 1h).

The relation between disorders and essential oils are given in Figure 1i. According to Figure 1i, participants with stress and anxiety were used thyme and St John Wort oils. For the skin care and diseases, participants mostly preferred sweet almond and turpentine oils. The participants specified that they purchased mint, flaxseed and black cumin oils for the losing weight and cancer prevention. In addition, participants with rheumatic disorders stated that they preferred purchasing St. John Wort and castor oils (Figure 1i).

One of the previous studies reported that participants with medium- and low-income levels (n=288) stated that purchasing factors of the aromatic and medicinal plants were odor, color and expiry date (Güney, 2019). In the same study reported that participants with high-income levels (n=112) indicated that purchasing factors of the aromatic and medicinal plants were odor, color, expiry date, price, brand (Güney, 2019).

Furthermore, Güney (2019) reported that using purposes of EOs by participants with low education level and medium income level were relaxation, flavor enhancers and habits while participants with high education and income levels were treatment, treatment support, disease prevention and to increase nutritional value. Again, in the same study, it was reported that using purposes of EOs of participants with middle-educated and low-income were treatment, treatment support and disease prevention. Additionally, researchers indicated that participants mostly used linden, black cumin and rose-ship for the medicinal concerns while participants mostly used as mint, black pepper, thyme, cinnamon, garlic and cumin for aromatherapy (Güney, 2019). In the same study, factors affecting consumption of participants with low education level were news, customs and traditions while participants with medium-education levels were pieces of advice from doctors and herbalists, news, customs and traditions, religious beliefs. At the same time, researchers indicated that factors affecting consumption of participants with high-education levels were pieces of advice from friends, herbalists, and doctors, advertisements, news, customs and traditions (Güney, 2019).

In a similar study conducted by Cadar et al. (2021) reported that consumers of the medicinal and aromatic plants (including essential oils) (MAPs) clustered three different groups according to frequency of the purchasing. Researchers indicated that cluster 1, 2 and 3 were formed” most often users,” “rarely users” and “occasional users,” respectively. In the same study, reported that the users of the cluster 1 includes women with a high level of education and higher incomes while products used as both phytotherapeutic and cosmetic purposes. For cluster 2 researchers reported that users who generally men, with lower education and incomes. Additionally, researchers reported that cluster 3 mostly including products for personal care and cosmetic purposes and users are both sexes, with medium education and incomes (Cadar et al., 2021). Literature results align with our findings.

Table 1. Questionnaire and frequencies of the respondents.

***Q1- Age?** ☐18-25 (44.2%) ☐26-35 (28.9%) ☐36-45 (18.7%) ☐46-55 (5.3%) ☐55+ (3.0)	*****Q9- Which factors mainly affecting your purchasing decision when buying aromatic oil?** ☐ Price (10.9%) ☐ Packs (5.1%) ☐ Trademark (19.5%) ☐ Certificate (30.2%)
***Q2- Gender?** ☐Female (58.3%) ☐ Male (41.7%)	***Q10. How often did you use / use this oil (s)?** ☐ Everyday (4.5%) ☐ Several times a week (30.5%) ☐ Several times a month (34.7%) ☐ Several times a year (30.3%)
***Q3- Marital status?** ☐ Married (40.7%) ☐ Single (59.3%)	*****Q11.For what purpose do you buy this oil (s)?** ☐ Cosmetics/Beauty (30.2%) ☐ Medicinal/Health (38.2%) ☐ Food supplement (4.0%)
***Q4- Education level?** ☐ Primary (4.3%) ☐ Senior (18.9%) ☐ University (65%) ☐ Master (8.4%) ☐ Ph.D .(3.4%)	*****Q12- Which resources do you get information about relationship between food and health?** ☐Television (2.3%) ☐internet (60.8%) ☐ Newspaper (0.3%) ☐ Journal (0.8%) ☐ Medical advice (4.5%) ☐ Others (2.5%)
***Q5- Monthly income level?** ☐0-1500 (31.7%) ☐1501-2500 (14.8%) ☐2501-3500 (18.2%) ☐3501-5000 (16.9%) ☐5000+ (18.4%)	*****Q13. Which of the oils listed below have you bought at least once?** ☐Sweet almond oil (2.7%) ☐Thyme oil (1.2%) ☐Turpentine oil ☐Rosemary oil ☐Castor oil (0.7%) ☐Apricot kernel oil ☐St. John's Wort oil (2.0) ☐Tea tree oil (0.7%) ☐Black cumin oil (4.2%) ☐Coconut oil (1.2%) ☐Lavender oil (1.2%) ☐Laurel oil ☐Flaxseed oil (0.2%) ☐Basil oil ☐Rose oil ☐Clove oil ☐Jojoba oil ☐Eucalyptus oil (0.2%) ☐Argan oil (1.0%) ☐Grape seed oil (0.5%) ☐Citrus oils (0.2%) ☐Pomegranate seed oil ☐Mint oil (0.2%) ☐Others
****Q6. Have you purchased any aromatic oils before?** ☐ Yes (66%) ☐ "No" because "I have no information" (22.8%) ☐ "No" because "I don't think it's useful." (8.2%) ☐ "No" because "I think it's expensive." (2.0%) ☐ "No" because "I don't believe they are pure and original." (1.0%)	*****Q14. Which are the reasons for use?** ☐Stress and anxiety (1.5%) ☐Weight loss / diet (1.7%) ☐Rheumatic disorders (3.0%) ☐Protection against cancer (0.7%) ☐Anti-aging ☐Skin care and diseases (13.4%) ☐Hair care (9.7%) ☐Varicosis ☐Asthma and respiratory disorders (3.0) ☐Others (4.5%)
*****Q7- Where do you get the aromatic oil you bought?** ☐ Herbalist (54.2%) ☐ Market (10.3%) ☐ internet (11.1%) ☐ Pharmacy (3.7%)	*****Q15. How and what did you use / use this oil (s) for?** ☐Food or food supplements (8.7%) ☐Cream or Lotion (60%) ☐Aromatherapy (4.7%)
***Q8- Are you sure that the aromatic oil you supply is pure and safe?** ☐ Yes, I am sure. (26.2%) ☐ No, I am not sure. (30.7%) ☐ I have doubts. (43.1%)	*****Q16. Do you think herbal solutions or alternative / complementary medicine are useful?** ☐ Yes, I am sure. (84.7%) ☐ No, I am not sure. (1.0%) ☐ I have doubts. (14.3%)

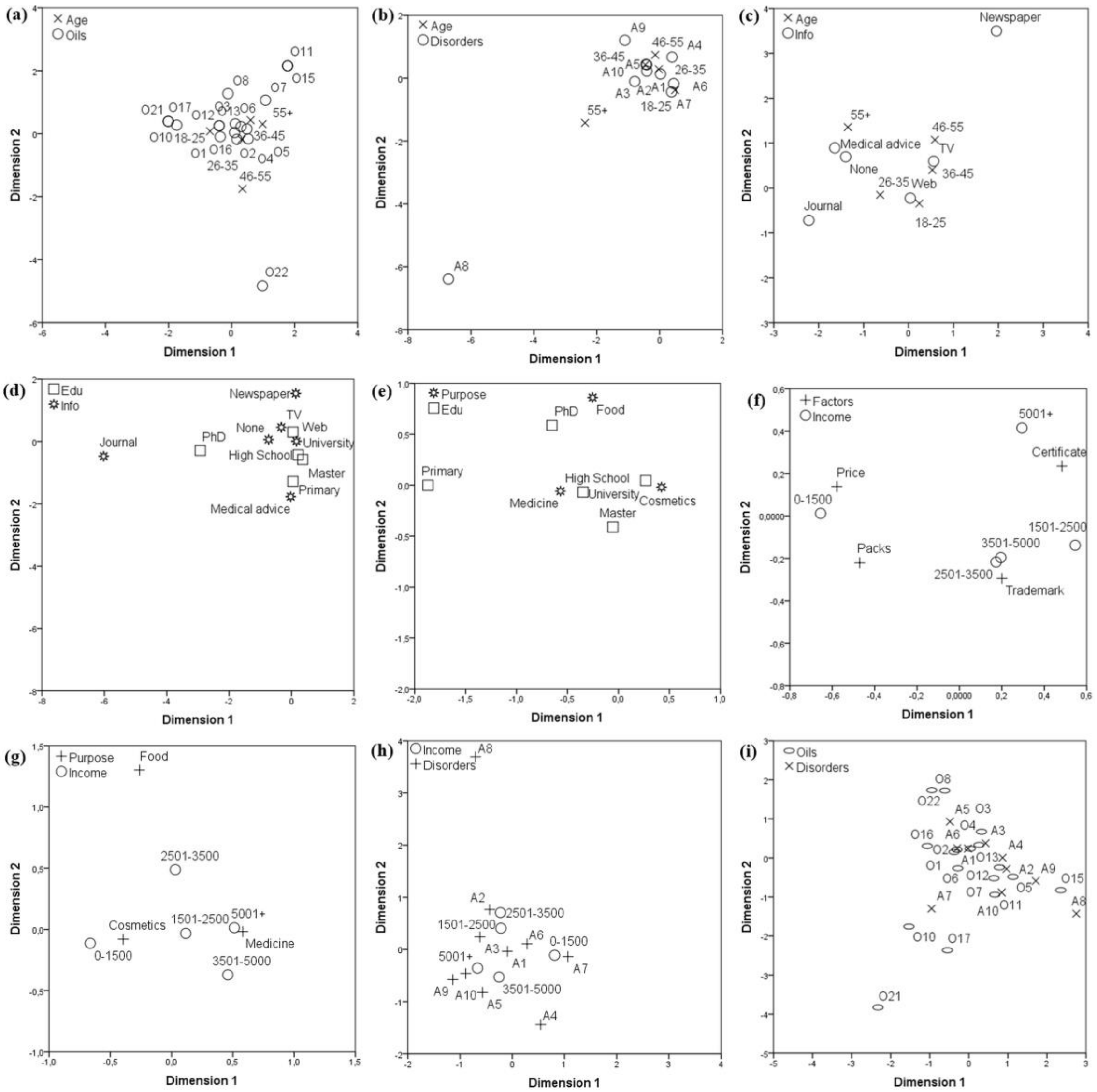

Figure 1. The correspondence analysis results on demographic data and essential oils consumed. *(a) relationships between consumer ages and consumed oils, (b) consumer ages and disorders, (c) consumer ages and received information about essential oils, (d) consumer education levels and received information about essential oils, (e) used purposes and education levels, (f) factors affecting purchasing motivations and monthly income, (g) used purposes and monthly income, (h) monthly income and disorders and (i) purchased oils and disorders.*

CONCLUSION

In this study, perceptions and purchasing motivations of the consumers on the essential oils successfully explained with 603 volunteer participants' different parts of Türkiye. It was observed that participants from different age groups mostly preferred the same essential oils, except 46-55 years. It was determined that only participants in the 55+ age group received medical advice regarding the essential oils they used. Additionally, it was determined that education levels of the respondents effective on the sources of information about EOs and usage purposes.

The perceptions and purchasing decision of the consumers on EOs were affected by both income level and disease history of the participants. In conclusion, participants with higher income level purchased black cumin oil against the asthma and respiratory disorders for medicinal expectations while participants with the lowest income levels purchased argan and coconut oils for cosmetic purposes, especially for hair care.

ETHICS COMMITTEE APPROVAL

Ethics approval was obtained with the meeting of Çanakkale Onsekiz Mart University Clinical Research Ethics Committee dated 14.04.2020 and numbered 2020-06.

CONFLICT OF INTEREST

The author declares that for this article, they have no actual, potential, or perceived conflict of interest.

REFERENCES

Aburjai T. & Natsheh F.M. 2003. Plants used in cosmetics, *Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives*, 17(9), 987-1000.

Aday M.S. & Yener U. 2014. Understanding the buying behavior of young consumers regarding packaging attributes and labels, *International Journal of Consumer Studies*, 38(4), 385-393.

Andreassen H.K., Bujnowska-Fedak M.M., Chronaki C.E., Dumitru R.C., Pudule I., Santana S. et al., Wynn R. 2007. European citizens' use of E-health services: a study of seven countries, *BMC Public Health*, 7, 1-7.

Bivins R.E. 2010. Alternative medicine? A history: Oxford University Press.

Cadar R.-L., Amuza A., Dumıtras D.E. & Pocol C.B. 2021. Consumer Behaviour Of Products Obtained From Medicinal And Aromatic Plants: A Segmentation Based On Frequency And Purpose Of Their Use, *Scientific Papers Series Management, Economic Engineering in Agriculture & Rural Development*, 21(2).

Chakravarty, I., Parmar, V. M., & Mandavgane, S. A. (2021). Current trends in essential oil (EO) production. Biomass Conversion and Biorefinery, 1-24.

Dhifi W., Bellili S., Jazi S., Bahloul N. & Mnif W. 2016. Essential oils' chemical characterization and investigation of some biological activities: A critical review, *Medicines*, 3(4), 25.

Edris A.E. 2007. Pharmaceutical and therapeutic potentials of essential oils and their individual volatile constituents: a review, *Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives*, 21(4), 308-323.

Goh J.W. & Ng A.H.H. 2021. Factors Affecting Online Consumer Buying Behavior Towards Essential Oils in Penang. *In Impact of Globalization and Advanced Technologies on Online Business Models*, IGI Global, pp. 279-302.

Güney O.I. 2019. Consumption attributes and preferences on medicinal and aromatic plants: a consumer segmentation analysis, *Ciência Rural*, 49.

Korkmaz M., Fakir H. & Guller B. 2011. Consumer preferences for medicinal and aromatic plant products: Surveys of urban consumers and sellers in western mediterranean region of Turkey, *Journal of Medicinal Plants Research*, 5(10), 2054-2063.

Mancini P., Marchini A. & Simeone M. 2017. Which are the sustainable attributes affecting the real consumption behavior? Consumer understanding and choices, *British Food Journal*, 119(8), 1839-1853.

Nandi R., Bokelmann W., Gowdru N.V. & Dias G. 2017. Factors influencing consumers' willingness to pay for organic fruits and vegetables: Empirical evidence from a consumer survey in India, *Journal of Food Products Marketing*, 23(4), 430-451.

Raut J.S, & Karuppayil S.M. 2014. A status review on the medicinal properties of essential oils, *Industrial Crops and Products*, 62, 250-264.

Ribeiro A.S., Estanqueiro M., Oliveira M.B. & Sousa Lobo J.M. 2015. Main benefits and applicability of plant extracts in skin care products, *Cosmetics,* 2(2), 48-65.

Samiee S., Shimp T.A. & Sharma S. 2005. Brand origin recognition accuracy: its antecedents and consumers' cognitive limitations, *Journal of international Business Studies*, 36, 379-397.

Shamri S.N., Suhaimi N.A.M. & Alwi A. 2021. The factors affecting the consumer buying behavior towards local brand of food product in Selangor, *Journal of Agrobiotechnology, 12(1S), 40-50.*

Singh A. & Verma P. 2017. Factors influencing Indian consumers' actual buying behavior towards organic food products, *Journal of Cleaner Production*, 167, 473-483.

Wald H.S., Dube C.E. & Anthony, D.C. 2007. Untangling the Web—The impact of Internet use on health care and the physician–patient relationship, *Patient Education and Counseling*, 68(3), 218-224.

Wangberg S.C., Andreassen H.K., Prokosch H.-U., Santana S.M.V., Sørensen T. & Chronaki C.E. 2008. Relations between Internet use, socio-economic status (SES), social support and subjective health, *Health promotion international*, 23(1), 70-77.

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Fortification with Selenium Markedly Affects Biological Efficiency and The Distribution of Essential and Non-Essential Amino Acids in *Pleurotus Ostreatus*

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Abstract

Mineral elements are very important in the metabolic processes of living things; hence their absence often results to deficiency diseases. This study reports the effects of selenium fortification on biological efficiency and the distribution of essential and non-essential amino acids in *P. ostreatus*. Viable spawn of *P. ostreatus* was inoculated into substrate spiced with Se while the control was *P. ostreatus* cultivated on substrate without Se. The biological efficiency was calculated using standard method while the amino acid content of the Se fortified and non fortified *P. ostreatus* was analysed using Applied Biosystems PTH amino acid analyzer. The biological efficiency (31.3%) of Se fortified *P. ostreatus* was lower compared to *P. ostreatus* not fortified with Se (43%). Moreover, there was reduction in essential amino acids in *P. ostreatus* fortified with Se, except Valine (50.0mg/100g) that was higher in Se fortified *P. ostreatus*. Generally, the percentage nitrogen in Se fortified *P. ostreatus* (4.79%) was slightly lower than what was obtained in non-selenium fortified *P. ostreatus* (5.05%). Data gathered from this study revealed that Se fortification markedly affects the biological efficiency, quantities and distribution of essential and non-essential amino acids in *P. ostreatus*.

Keywords: *Pleurotus ostreatus*, Selenium, Fortification, Distribution, Amino acids, Essential, Non-essential.

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INTRODUCTION

Edible mushrooms had been part of human diet from time immemorial. Mushrooms have long been used as a valuable food source and as traditional medicines around the world, especially in Japan and China (Oyetayo, 2011). Generally, edible mushrooms are rich in nutrients such as high quality protein of 10% to 40%, carbohydrate of 3% to 21% and dietary fiber of 3% to 35% on dry weight basis depending on the species (Mallavadhani et al., 2006). Consumption of mushrooms as healthy food is therefore based on their rich proteins, minerals, poor calories and fat (Wang et al., 2018).

Mushrooms also produce secondary metabolites which possess anticancer, antiviral, antibacterial, antifungal and anti-inflammatory properties (Owaid et al., 2015). The presence of mycochemicals such as polysaccharides, proteins, terpenes, phenolic compounds and unsaturated fatty acids, and many other substances of different origin (Barros et al., 2007; Oyetayo et al., 2012; Ogidi et al., 2020) actually confers health promoting properties mentioned above on mushrooms (Oyetayo, 2023). These mycochemicals with pharmacological properties are found in the fruitbodies and the culture filtrates of mushrooms (Oyetayo and Akingbesote, 2022). One unique attribute of mushrooms is their ability to absorb nutrient from substrates on which they are cultivated and bioaccumulate them as functional compounds with nutraceutical, pharmaceutical and cosmeceutical potentials (Ogidi et al., 2020). Mineral elements play very important roles in the metabolic processes of plants and animals. The bio-accumulation of these mineral elements by mushrooms affects the metabolic products generated and their nutraceutical properties (Oyetayo, 2023).

Oyster mushrooms are well known edible mushrooms. *P. ostreatus*, a popular oyster mushroom, is a commonly cultivated edible mushroom (Da Silva *et al*., 2019), and hence, it is of great economic and nutritional importance (Fekry *et al*., 2021). During cultivation, *P. ostreatus* can bio-accumulate mineral elements to form bioactive compounds. Selenium enrichment cultivation is a good strategy for increasing the bioactivity of mushroom since enrichment will enhance the production of Selenium metabolites particularly selenium-polysaccharides, selenium-proteins and seleno-amino acids (Zhu *et al*., 2021). Higher bioactivities in terms of antitumor, antioxidant, antimicrobial, and anti-inflammatory properties of Se enriched mushroom when compared with non-selenium fortified has been attributed primarily to the presence of Se-polysaccharide complexes (Cheng *et al*., 2023). Selenium can be bio-accumulated as selenoprotein which are useful in preventing various types of cancer and diseases like diabetes, age-related immunosuppression and even problems related to fertility (Dwyer *et al*., 2015). Biofortification of *P. ostreatus* and *P. eryngii* with Selenium was observed to significantly improve their antioxidant and reducing activities, indicating the potential applicability of such bio-fortified ingredients as functional food (Poniedzialek *et al*., 2017). Other reports showed that fortifications with mineral elements such as Se, Fe, and Zn positively impact antioxidant and antimicrobial properties of *Pleurotus* species extracts (Fasoranti *et al*., 2018; Fasoranti *et al*., 2019; Oyetayo *et al*., 2021; Oyetayo *et al*., 2024). Moreover, a recent report also revealed that Se and Fe fortification markedly affected the phytochemical and amino acid contents of *P. ostreatus* (Fadugba *et al*., 2024). This study therefore seeks to evaluate the effect of Se fortification on biological efficiency and distribution of essential and non-essential amino acids in *P. ostreatus*.

MATERIALS AND METHODS

Artificial cultivation of Selenium fortified and non-fortified *Pleurotus Ostreatus*

Viable spawn of *Pleurotus ostreatus* purchased obtained from the Federal Institute of Industrial Research, Oshodi (FIIRO), Lagos, Nigeria was artificially cultivated on rice bran and saw dust. The method of Fadugba *et al*. (2024) was adopted for the cultivation of *Pleurotus ostreatus*. Briefly, the substrates (sawdust and rice bran) were mixed together in the ratio 3:1. (60% of saw dust plus 20% rice bran) and moistened with water to prevent dryness.

About 700 g of the substrate was packed into polypropylene bag and sealed with paper with the aid of polyvinyl rings and this was sterilized in an autoclave and allowed to cool to room temperature (26 ± 2^{o}C). Thereafter, 8 ml of Sodium selenite (Na_2SeO_3) at a concentration of 50 mg/kg was injected into the some bag containing for Selenium fortification. A control treatment with no sodium selenite was also prepared. Following this, substrates in separate bags were inoculated with 30 g of spawn. The bags were kept in the dark room with relative humidity of 75% to ramify.

Determination of biological efficiency

The biological efficiency (BE) was calculated using the formular below.
BE = (weight of fresh mushroom/weight of dried substrate) × 100.

Determination of Amino acid content of Selenium fortified and non-fortified *Pleurotus Ostreatus*

The amino acid profile of Selenium fortified and non-fortified *Pleurotus ostreatus* was determined using the method of AOAC (2006). The sample was defatted using chloroform/methanol mixture of ratio 2:1. About 5 g of the sample was put in extraction thimble (or filter paper) and extracted for 15 hours in soxhlet extractor. The sample (200 mg) was weighed and placed in a Kjeldahl flask with 200 mg of different catalysts (Potassium sulphate, Copper sulphate and Selenium powder). Concentrated Sulphuric acid was also added to the content of flask. The mixtures were gently heated for a few seconds until frothing ceased and the heat increased for 1 h 30 min to enhance digestion. It was cooled and distilled water was used to make a known volume (100 cm^3). An aliquot of diluted solution of the digest was piped into distillation chamber of micro Kjeldhal distillation apparatus.

Sodium hydroxide solution (40%) was added and it was steamed into 10.0cm^3 of 4% boric acid containing mixed indicator. It was titrated with standard 0.01N hydrochloric acid. The samples were hydrolyzed by using 7 ml of 6N HCl which was placed in an oven preset at 105 °C ± 5 °C for22 h. The filtrate was evaporated to dryness while the residue was dissolved with 5 ml acetate buffer. 60 µl of each samples were loaded each into the applied biosystems PTH amino acid analyser. The concentrations of the amino acids (in g/100g protein) were calculated from external standards for the different amino acids.

Data Analysis

Data generated were analysed using one-way Analysis of variance (ANOVA), using SPSS 20.0.

RESULTS AND DISCUSSION

Selenium fortification reduced the yield and subsequently the biological efficiency (BE) of *P. ostreatus* fruitbodies (Figure 1). In this study, BE of Se enriched *P. ostreatus* (31.3%) was lower than what was observed in *P. ostreatus* (43%) not enriched with Se. In a previous study, Fekry *et al*. (2021) reported that at 20.0 mg/L Se concentration, *P. ostreatus* biomass reduced from 5.56 g/L to 3.20 g/L, and at concentration of 40.0 and 60.0 mg/L Se concentration, biomass production was significantly suppressed. High Se had been reported to prevent growth and mycelium production in *P. ostreatus* (Da Silva *et al*., 2013). Growth inhibition of another

Figure 1. Biological efficiency of Selenium fortified and non-fortified *P. Ostreatus*

SeFM: Selenium fortified mushroom; NFM: Non-selenium fortified mushroom

mushroom, *Inonotus hispidus,* was also observed at higher Se concentration (Song *et al*., 2022). The concentration of 50mg/kg injected into the substrate used in this report was still within the range 40 to 60 mg/l Se concentration that still allowed the growth of the mushroom (Fekry et al., 2021). Tangiadee *et al*. (2023) recently reported that presence of selenium affect oxidative activities in cells and higher concentration of selenium alter biomass production. Generally, the translocation of minerals from substrate affects the productivity, chemical /sensory characteristics and biological efficiency of mushroom (Fekry *et al*., 2021).

Glutamic acid was the most abundant amino acid in Selenium fortified and non fortified *P. ostreatus* with values of 164.3mg/g and 181.1 mg/g respectively. This is in conformity with previous reports that showed glutamic acid is the highest occurring amino acid in *Pleurotus* species (Oyetayo *et al*., 2007; Oyetayo and Ariyo, 2013; Fasoranti *et al*., 2019). However, Se fortification was observed to cause reduction in all the essential amino acids except Valine (Table 1). On the other hand there was increase in the following non essential amino acids, Alanine, Proline, Glycine, Tyrosine, in Se fortified *P. ostreatus* (Table 2).

Table 1. Essential Amino acids (g/100g) in Selenium fortified and Non-fortified *P. ostreatus*

Amino Acid	**NFM**	**SeFM**
Valine	45.9 ± 0.01	49.1 ± 0.05*
Leucine	52.9 ± 0.01	47.2 ± 0.06
Lysine	26.2 ± 0.03	22.3 ± 0.03
Isoleucine	34.1 ± 0.01	29.2 ± 0.19
Histidine	13.0 ± 0.02	11.3 ± 0.01
Tryptophan	11.9 ± 0.01	9.1 ± 0.01
Methionine	12.4 ± 0.01	11.4 ± 0.01
Phenylalanine	44.0 ± 0.02	40.7 ± 0.01
Threonine	46.5 ± 0.66	37.1 ± 0.03

*NFM: Non selenium fortified mushroom; SeFM: Selenium fortified mushroom. * Amin acid higher in SeFM*

Table 2. Non-essential Amino acids (mg/g) in Selenium fortified and Non-fortified *P. ostreatus* fruitbodies

Amino Acid	**NFM**	**SeFM**
Alanine	41.7± 0.05	44.5 ± 0.03*
Proline	35.2 ± 0.01	37.7± 0.00*
Glycine	33.6 ± 0.02	36.0 ± 0.03*
Tyrosine	29.1 ± 0.01	30.9 ± 0.01*
Glutamic acid	181.1 ± 0.12	164.3 ± 0.13
Aspartic acid	35.5 ± 0.02	36.1 ± 0.10
Arginine	54.6 ± 0.02	49.4± 0.03
Serine	66.4 ± 0.33	52.8± 0.03
Cysteine	13.5 ± 0.03	11.8 ± 0.02

*NFM: Non selenium fortified mushroom; SeFM: Selenium fortified mushroom. * Amino acid higher in SeFM*

Both the total essential and non essential amino acids were lower in Se fortified *P. ostreatus* than Non-selenium fortified *P. ostreatus* (Table 3). This could be as a result of the inhibition of growth of *P. ostreatus* at Se concentration above 20.0 mg/L (Fekry *et al.*, 2021). Amino acids which are primary products of metabolism are produced during growth of mushrooms (Yang *et al.*, 2020). It was also recently reported by Xiang *et al*. (2023) through transcriptomic profiling that high enrichment for amino acid metabolic pathways in primordia are essential for growth and fruiting body formation in the mushroom, *Hypsizygus marmoreus*. Moreover, It has been reported that metabolism of certain amino acid affects the level of certain amino acids due to the biosynthesis and catabolism of amino acids derived from the same metabolic trunk and /or closely related to other metabolic pathways acting as substrate or intermediate (Song *et al.*, 2022). The inhibition / alteration of growth by Se fortification may have affected the quantity and distribution of amino acids produced of *P. ostreatus.*

Table 3. Total essential and non-essential amino acids (mg/g) of Selenium fortified and Non fortified *P. ostreatus* fruitbodies

Amino Acid	NFM	SeFM
Total amino acid	780.6	713.4
Total essential Amino acid	286.9	257.4
Total Non essential Amino acid	490.7	463.5

The quality of dietary proteins can be measured in many ways but it is the ratio of available amino acids in the food compared with the needs as a ratio (Bender, 1992). The quality of proteins in *P. ostreatus* when compared with FAO (2013) standard (Table 4) revealed Phenylalanine/ Tyrosine (1.19 - 1.22); Threonine (0.93 – 1.1) and Valine (0.92 -0.98) were the highest scoring essential amino acid in both Se fortified and non-Se fortified *P. ostreatus* (Table 5). From the data in Table 5, Se fortified and non-Se fortified *P. ostreatus* are good protein sources since they contain essential amino acids in appreciable quantities which are capable of enriching human diets and reducing the incidence of protein-energy malnutrition (Oyetayo *et al*., 2007).

Table 4. Provisional Amino acid scoring pattern

Amino Acid	Suggested level (mg/g protein)	Mg/g N
Isoleucine	250	40
Leucine	440	70
Lysine	340	55
Methionine/ Cysteine	220	35
Phenylalanine/ Tyrosine	380	60
Threonine	250	40
Valine	310	50

Table 5. Calculated amino acid scores of cultivated and wildly obtained *P. ostreatus* fruitbodies.

Amino Acid	NFM	SeFM
Isoleucine	0.85	0.67
Leucine	0.76	0.73
Lysine	0.48	0.48
Methionine/ Cysteine	0.74	0.66
*Phenylalanine/ Tyrosine	1.22	1.19
*Threonine	1.16	0.93
*Valine	0.92	0.98

**Amino acids with the highest score*

In conclusion, Se fortification markedly affected the BE and distribution of essential and non-essential amino acids in *P. ostreatus* though the overall quality of its protein was not too affected when compared with FAO (2013) standard.

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REFERENCES

AOAC 2006. Association of Official Analysis, 18th Edition. Horwitz .W Editor, Washington, D. C.

Barros L., Baptista P., Correia D.M., Casal S., Oliveira B. & Ferreira C. R.F. 2007. Fatty acid and sugar compositions, and nutritional value of five wild edible mushrooms from Northeast Portugal. *Food Chemistry*, 105, 140–145.

Cheng K., Sun Y., Liu B., Ming J., Wang L., Xu C., Xiao Y., Zhang C. & Shang L. 2023. Selenium Modification of Natural Products and Its Research Progress. *Foods*. 13;12(20), 3773. doi: 10.3390/foods12203773.

Da Silva M. C. S., Mateus D. N., Jose Maria R. da Luz, & Maria C.M. K. 2013. Mycelial Growth of & lt;I >Pleurotus </I > Spp in Se-Enriched Culture Media. *Advances in Microbiology*, 03(08), 11-18.

Da Silva M. C. S., José M. R. da Luz, Ana P. S. P., Daniele R. M., Alexandrina A. C., Juliana N. & Maria C. M. K. 2019. Growth and Tolerance of *Pleurotus Ostreatus* at Different Selenium Forms. *Journal of Agricultural Science*, 11(2), 151.

Dwyer J.T, Wiemer K.L., Dary O., Keen C.L. & King J.C et. al. 2015, Fortification and health: challenges and opportunities. *Adv Nutr*, 6,124–131.

FAO 2013. Dietary protein quality evaluation in human nutrition. Report of an FAO Expert Consultation.https://www.fao.org/ag/humannutrition/35978-02317b979a686a57aa4593304ffc17f06.pdf

Fadugba, A.E., Oyetayo, V.O., Osho, I.O. & Olaniyi, O.O. 2024. Assessment of the effect of iron and selenium fortification on the amino acids profile of *Pleurotus ostreatus*. *Vegetos* doi: 10.1007/s42535-024-00820-8

Fasoranti O.F., Ogidi, C.O. & Oyetayo, V.O. 2018. Phytochemical constituents and antimicrobial evaluation of ethanolic extracts from *Pleurotus* spp. cultivated on substrat fortified with selenium. *Microbial Biosystems*, 3(2), 29-39.

Fasoranti O. F., Ogidi C.O. & Oyetayo V.O. 2019. Nutrient Contents and Antioxidant Properties of *Pleurotus* spp. Cultivated on Substrate Fortified with Selenium. *Current Research in Environmental and Applied Mycology*, 9(1), 66–76.

Fekry T., AbdElaziz1 A.A., Muawia1 S., Naguib, Y.M., Khalil H. & Salem M.F. 2021. Effect of Absorption Selenium (Se) on Mycelium Growth of *Pleurotus ostreatus* Mushrooms. *Frontiers in Science*, 11(1), 18-23. doi: 10.5923/j.fs.20211101.02

Mallavadhani U.V., Sudharkar A.V., Satyanarayana K.V., Mahapatra A., Li W. & Van Breemen R.B. 2006. Chemical and analytical screening of some edible mushrooms. *Food Chemistry*, 95:58-64

Ogidi C.O., Oyetayo V.O. & Akinyele B.J. 2020. Wild medicinal mushrooms: potential applications in phytomedicine and functional foods. In: An Introduction to Mushroom. *IntechOpen.* ISBN 978-1-78985-956-0.

Oyetayo F.L., Akindahunsi A.A & Oyetayo V. O. 2007. Chemical profile and amino acids composition of edible mushrooms, *Plerotus sajor-caju*. *Nutrition and Health*, 18, 383 – 389.

Oyetayo V.O. 2011. Medicinal Uses of Mushrooms in Nigeria: Towards Full and Sustainable Exploitation. *African Journal of Traditional, Complementary and Alternative medicines*. 8(3), 267-274.

Oyetayo V.O., Nieto-Camacho A., Baldomero E. R. & Jimenez M. 2012. Assessment of Anti-inflammatory, Lipid Peroxidation and Acute Toxicity of Extracts Obtained From Wild Macrofungi Collected From Akure Southwest Nigeria. *International Journal of Medicinal Mushrooms,* 14(6), 573–578.

Oyetayo V.O. & Ariyo O.O. 2013. Antimicrobial and Antioxidant Properties of *Pleurotus ostreatus* Cultivated on Different Tropical Woody Substrates. *Journal of Waste Conversion Bioprocessing and Biotechnology*, 1(2), 28-32.

Oyetayo V.O., Ogidi C.O., Enikanselu F.F. & Bayode S.O. 2021. Evaluation of Biological Efficiency, Nutrient Contents and Antioxidant Activity of Zinc –or and Iron –enriched Oyster Mushroom. *Indian Phytopathology*. doi: 10.1007/s42360-021-00410-7

Oyetayo, V.O. & Akingbesote, E.T. 2022. Assessment of the Antistaphylococcal Properties and Bioactive Compounds of Raw and Fermented *Trametes polyzona* (Pers.) Justo Extracts. *Microbial Biosystems*, 7(1).

Oyetayo V.O. 2023. Mineral Element Enrichment of Mushrooms for the Production of More Effective Functional Foods. *Asian J. Biol. Sci*., 16 (1), 18-29

Oyetayo V.O., Ogidi C. O., Enikanselu F. F. Fadugba A. E. & Bayode S. O. 2024 Anticandidal and Antistaphylococcal potentials of extracts of *Pleurotus pulmonarius* fortified with Zinc and Iron. *Vegetos* doi: 10.1007/s42535-024-00852-0

Owaid M.N., Abed, A.M. & Nassar B.M. 2015. Recycling cardboard wastes to produce blue oyster mushroom *Pleurotus ostreatus* in Iraq. *Emir. J. Food Agric*., 27 (2015), 537-541

Poniedziałek B., Mleczek M., Niedzielski P., Siwulski M., Gasecka M., Kozak L., Komosa A. & Rzymski P. 2017. Bio-enriched *Pleurotus* mushrooms for deiciency control and improved antioxidative protection of human platelets? *Eur Food Res Technol,* 243, 2187–2198.

Song F., Su D., Keyhani N.O., Wang C., Shen L. & Qiu J. 2022. Influence of selenium on the mycelia of the shaggy bracket fungus, *Inonotus hispidus*. *Journal of the science of Food and Agriculture*. 102 (9), 3762-3770.

Tangiadee P., Swedlund P., Xiang J., Yin H. & Quek S.Y. 2022. Selenium-enriched plant foods: Selenium accumulation, speciation, and health functionality, 9, 962312. doi: 10.3389/fnut.2022.962312

Wang W., Xu M., Wang G. & Galili G. 2018. New insights into the metabolism of aspartate-family amino acids in plant seeds. *Plant Reprod*, 31, 203–211. doi: 10.1007/s00497-018-0322-9

Xiang Q., Arshad M., Li Y., Zhang H., Gu Y., Yu X., Zhao K., Ma M., Zhang, L., He M. & Chen, Q. 2023. Transcriptomic profiling revealed important roles of amino acid metabolism in fruiting body formation at different ripening times in *Hypsizygus marmoreus*. *Frontiers inMicrobiology*. doi: 10.3389/fmicb.2023.1169881

Yang Q., Zhao D. & Liu Q. 2020. Connection between amino acid metabolisms in plants: Lysine as an example. *Frontiers in Plant Science*, 11, Article 928, 1- 8.

Zhu S., Li Y., Xu S., Shi G. & Ding Z. 2021. Effect of selenium on mushroom growth and metabolism: A review. *Trend in Food Science and Technology*, 118 (A), 328-340