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Evaluation of edible oil types used in packaged foods in Türkiye with principal component analysis

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Abstract: In our rapidly changing world, where consumers' expectations for healthy food are on the rise, the edible oil content in packaged foods has become a central focus. Among various types of oils, palm oil is often regarded as one of the most contentious. This research study aimed to identify the types of fats present in packaged food products in Türkiye and examined the reasons for their utilization. A total of 1380 packaged food items, classified into 11 categories, were scrutinized, and the types of oils within their ingredients were classified using principal component analysis and hierarchical cluster analysis. The study's results have determined that among packaged food products available in Türkiye, 50.1% contain palm oil, 30.4% contain sunflower oil, 16.4% contain canola oil, 14.9% contain cottonseed oil, 17.9% contain cocoa oil, and 12.6% contain coconut oil. In particular, it was determined that palm oil was used in 91% of bakery products, 81% of margarine and shortening products, and 71.3% of ice creams. Consequently, the data obtained in the context of ongoing debates regarding the fat content in packaged foods, especially concerning palm oil usage, will make a valuable contribution to the literature.

KEYWORDS
edible oils, food labeling, hierarchical cluster analysis, palm oil, principal component analysis

1 | INTRODUCTION

Fats, one of the three basic energy sources required for vital activities to continue smoothly, are an indispensable part of human nutrition. The production of butter substitutes began in Europe in the mid-19th century, mainly due to the high prices of animal oils such as tallow and butter used traditionally around the world (Shahidi, 2005). Margarines based on partially hydrogenated oil containing TFA (*trans* fatty acid) are less expensive to produce than butter or lard. As a result of the studies, the determination that TFA is associated with heart disease has shown that partially or fully hydrogenated vegetable oil varieties cause cardiovascular diseases (Menaa et al., 2013; Pase et al., 2021; Stender & Jorn, 2006). TFAs are frequently used in commercial products because they give the desired taste and texture to foods, are economical, and can be stored for a long time without spoiling. Increasing consumer awareness of the health effects of TFAs has resulted in efforts both nationally and internationally to limit or ban the use of these fatty acids by restaurants and food service establishments (Martin et al., 2007; Verneque et al., 2020). Health concerns about fat substitutes highlight technological techniques such as the modification of certain natural fats or oils. Although a wide variety of oils such as soybean, sunflower, canola, and cottonseed oils, which are

frequently used in food technology, are used, one of the most controversial oils today is palm oil with the highest usage rate. Thus, recently palm oil and its derivatives have gained great importance in order to meet producer and consumer expectations (Fattore & Fanelli, 2013; Savarese et al., 2022).

Palm oil is the most widely used vegetable oil in the world, and its production and consumption are increasing every year. Palm oil had a consumption rate of 57.52 million mt in 2013, whereas 76.04 million mt is consumed 10 years later in 2022 (Statista, 2023). With a yield per hectare of about nine times that of soybeans and seven and a half times that of rapeseed, it can be said that palm plant is the most productive oily plant. In order to provide the amount of oil obtained from the palm plant, it is necessary to plant 5–10 times more than other oil-producing plants (Disdier et al., 2013; Verneau et al., 2019). Concerning human health, consumption of palm oil-rich foods is associated with an increased risk of cardiovascular disease given their high content of saturated fats such as palmitic acid (C16:0), myristic acid (C14:0), and lauric acid (C12:0) (Savarese et al., 2022; Sulaiman et al., 2022; Wassmann et al., 2023). On the contrary, it is also reported that there are no adverse effects of consuming date palm oil on health. As a result, it is difficult to say whether palm oil is completely healthy and safe (Fattore & Fanelli, 2013; Gesteiro et al., 2019; Sulaiman et al., 2022). In addition to health, discussions about palm oil are associated with environmental problems such as deforestation, loss of biodiversity, water pollution, and social problems such as exploitation of growers and child labor (Plasek et al., 2021; Savarese et al., 2022). For these reasons, palm oil can create negative connotations in consumers, and consumers may have negative attitudes toward palm oil-containing foods that may affect their purchasing behavior (Plasek et al., 2021).

Palm oil, which has a wide area of use in the food industry, stands out compared to alternative oils in terms of being cheap, being added to many food groups in food processing technology, and providing unique functionality. Palm oil is rich in C:16 and C:18 fatty acids, whereas palm kernel oil is rich in the C:12 fatty acid. Palm oil has a balanced percentage of fatty acids, including 50% saturated fatty acids, 40% monounsaturated, and 10% polyunsaturated fatty acids. This balanced composition of fatty acid keeps palm oil in a semisolid state and is more resistant to lipid oxidation than other vegetable oils containing high monounsaturated acids. Of the 50% of the saturated fatty acids, 45% is palmitic acid, and 5% is stearic acid (Shahidi, 2005). The palm olein form of palm oil has high oleic acid content and is preferred in frying, cooking, and baking food products because it is resistant to oxidation at high temperatures thanks to the antioxidants it contains. By mixing palm olein and palm stearin fractions with other oils such as sunflower–soybean, structural properties can be improved considerably, especially in bakery products. It can also be used in foods such as chocolate and chocolate-coated products as an alternative to cocoa oil, which is an expensive fat. The possibilities of using palm oil and palm kernel oils in many foods such as spreadable foods, margarines, candies, ice creams, creams, coffee whiteners, and salad dressings are increasing (Capecchi et al., 2019; Plasek et al., 2021).

Modification of oils used in foods (hydrogenation, interesterification, and fractionation) is also a frequently encountered application (Kellens & Calliauw, 2013). One of the modification methods of fats is interesterification, which rearranges the chemical or enzymatic distribution of fatty acids in and among triglycerides. Thus, the fatty acid distribution changes, but the fatty acid composition remains the same. It is possible to produce TFA-free oils by changing the melting and crystallization behavior of the oil with interesterification. Interesterification is a method that allows oils such as palm oil, which contains a high percentage of saturated fatty acids, to be mixed in a balanced ratio with unsaturated fatty acids and to obtain oils with desired properties. Thus, fat substitutes with the desired fatty acid profile and providing the desired melting, texture, and so on in foods can be produced (Temkov & Mureșan, 2021; Van Duijn, 2005). Another method of modification of oils is fractionation. The main principle of fractionation of fats is the separation of existing triacylglycerols with different melting points (depending on molecular weight and degree of unsaturation) into two different products (stearin and olein) that can be further processed. The fractionation process was commercialized several decades ago and has been used to obtain palm oil fractions for use in all sorts of different products (stable creams, sauces, infant formula, ice cream, baked goods, and chocolate) (Sulaiman et al., 2022). Fractions obtained from natural oils such as coconut, palm, and palm kernel oils were the components of functional ingredients oils. These oils, which have a high content of saturated fatty acids (50%) and higher melting points, have been accepted as candidates to replace partially hydrogenated fats, especially in bakery and confectionery products (Kellens & Calliauw, 2013; Van Duijn, 2005).

Soybean oil found in packaged foods is the second most used vegetable oil in the world, and its consumption rate is 60.32 million mt in 2022 (Statista, 2023). Soybean oil is rich in unsaturated fatty acids, which are healthy for human health but show poor oxidative stability. Regular soybean oil contains approximately 54% linoleic acid (C18:2), 23% oleic acid (C18:1), 11% palmitic acid (C16:0), 8% linolenic acid (C18:3), and 4% stearic acid (C18:0) (Walsh, 2007). The production and consumption rates of soybean oil in

Türkiye are quite low. Canola oil is the third most widely used vegetable oil in the world, with a consumption rate of 31.21 million mt in 2022 (Statista, 2023). Canola oil is considered very healthy oil due to its fatty acid composition. It typically contains approximately 60% oleic acid (C18:1), 20% linoleic acid (C18:2), and 10% linolenic acid (C18:3), making it a significant source of both omega-6 ($\omega - 6$) and omega-3 ($\omega - 3$) fatty acids (Barthet, 2016). Sunflower oil is the fourth most used vegetable oil in the world, and its consumption rate is 18.58 million mt in 2022 (Statista, 2023). Sunflower oil contains approximately 15% saturated and 85% unsaturated fatty acids, and its unsaturated fatty acid content consists of 14%–43% oleic acid (C18:1) and 44%–75% linoleic acid (C18:2). It is the edible oil with the most production and consumption in Türkiye. Sunflower oil is high in polyunsaturated fat and is widely used in the preparation of sauces and the production of spreads as a substitute for cooking or frying oil (Akkaya, 2018). Cottonseed oil has a fatty acid profile consisting of approximately 75% unsaturated fatty acids and 25% saturated fatty acids (Yang et al., 2019). Cocoa oil primarily consists of approximately 65% saturated fatty acids, mainly stearic acid (C18:0), and palmitic acid (C16:0), with unsaturated fatty acids making up around 35% of its composition (Diomandé et al., 2022). Roughly 90% of coconut oil is composed of saturated fats, with around 10% being unsaturated fats. Over 50% of the fats in coconut oil are medium-chain fatty acids, including lauric acid (C12:0) (Boateng et al., 2016). In addition to the four oils mentioned in packaged foods, vegetable oils, such as corn, linseed, hazelnut, safflower, and peanut oils, and animal oils, such as butter, are also used in smaller amounts.

Consumers in developed countries show great interest in the facts about the production techniques and ingredients of the foods they consume. With the increase in label literacy day by day, the ingredients of foods can be followed with interest. The debate on the health risks of palm oil consumption, which is one of the most popular topics, continues without any evidence and leads to ambiguous perceptions in the world public opinion. As a result, palm oil-free products are assumed to be healthier and more sustainable food products. Although there is no official label confirming the absence of palm oil in food products in the EU, in line with social demands, manufacturers and retailers have voluntarily started to indicate that their products do not contain palm oil on their labels (Borrello et al., 2019). Alternative oils with a certain amount of saturated fatty acids used in foods in accordance with the expectations of producers and consumers have gained even more importance with the emergence of health risks of TFA. In this sense, despite the opinions that it is harmful to health and causes environmental destruction, palm oil is the most important alternative oil that can be found in foods.

In this study, packaged foods available in Türkiye were categorized into 11 categories, and the types of vegetable oils listed in the ingredients section were identified. In this respect, although this study is specific to Türkiye, it can represent the generality of food products in 11 categories around the world. However, in some countries, as sunflower oil is not as common as in Türkiye, and oils such as soybean and canola oils are widely consumed, there may be changes in the contents of packaged foods. However, this is in line with the intended use of sunflower oil and is aimed at consuming oils rich in unsaturated fatty acids. Even though they come from different vegetable oil sources, their saturated fatty acid and unsaturated fatty acid contents form the consumption habits of societies according to geographical conditions. Consumption of palm oil is an issue that concerns the consumption habits of the whole world. The study examined which type of oil was predominantly used in each category and the reasons for using that specific type of oil in terms of food processing technology using the principal component analysis (PCA) and hierarchical cluster analysis (HCA) methods.

The aim of this study is to determine the usage rates of all oils, including palm oil, which has been a widely discussed ingredient in foods recently, in packaged foods throughout Türkiye. If an acceptable or unacceptable risk factor emerges in the future regarding palm oil, or if there is a change in consumer attitudes toward the use of palm oil, the data we have obtained will contribute significantly to the literature. Additionally, conducting similar studies in different countries and creating literature on the types of oils used in packaged foods can be a direct source of policies to be developed.

2 | MATERIALS AND METHODS

2.1 | Data collecting

Market research on the types of oil contained in packaged foods consumed in Türkiye was carried out through five national supermarket chains. In the selection of the five national supermarket chains, the markets with the highest market share and the most product variety were preferred. In this way, the geographical scope was kept wide by providing access to packaged foods with the highest market share available for consumption throughout the country. Official permission and ethics committee approval were obtained from all supermarket chains and administrative authorities included in this study. In order to examine the label information of the oil types used in food products in supermarkets, 11 food categories were determined. Categories were determined as bakery products, ready-to-eat foods, spreads-sauces, margarine-shortenings, pastry

ingredients, snacks, chocolate-wafer, ice-cream, emulsified meat products, breakfast cereals-bars-baby foods, and powdered drinks (Ricardo et al., 2019). Packaged food products that are unlikely to contain vegetable oil, such as fat-free drinks, honey products, and dairy products, were not examined. The number of samples was increased by adding categories such as emulsified meat products and powdered drinks that may contain vegetable oil.

At least three photos were taken, including the front of each package and the ingredient list. For the healthy progress of the data collection process, the photographs taken were quickly coded and saved. Generally, it is preferred to photograph large size products in similar products. Data collection, classification, and recording processes for this study were carried out by two field workers. The first of the field workers has expertise in dietetics and the second in the field of food engineering. All field workers have training in food composition, food labeling. In addition, field workers photographed products using smartphones with high-resolution cameras. In order not to disrupt the operation of supermarkets, data collection was carried out on Tuesdays, Wednesdays, and Thursdays, and the entire process was completed within 2 months in 2022. Field workers tried not to communicate with customers, emphasizing that this was "an ordinary labeling exercise" when necessary. As a result of all these studies, 1380 samples were examined one by one and approximately 5049 photographs were taken. All the methods used in the collection and classification of labeling data were developed by Kanter et al. (2017) and carried out by adapting their working model.

2.2 | Principal component analysis (PCA) and hierarchical cluster analysis (HCA)

The utilization of PCA and HCA in food science research has seen an increase in recent years due to their results being easily interpretable and discussable, particularly when analyzing extensive datasets. PCA is a statistical test within the realm of factor analysis. The primary goal of PCA is to mathematically represent the existing variation in a dataset using a limited number of factors. For visual analysis purposes, typically, two- or three-dimensional projections are generated where the axes, known as principal components (PCs), represent the factors, and the samples. Each PC is a linear combination of the original responses, and these PCs are orthogonal to one another. HCA, which is a clustering method, explores the arrangement of samples into groups and depicts hierarchical relationships both within and between these groups. The outcomes of HCA are typically represented in dendrograms, which are plots illustrating the organizational structure of samples in a treelike format. Although both PCA and HCA are highly valuable for studying data structure and identifying similarities among samples, it is worth noting that linear correlation coefficients often yield very similar interpretations of the results. The PCA and HCA data generated by JMP Pro were analyzed into JMP Pro (Ver 17, SAS Inc.).

3 | RESULTS

3.1 | Evaluation of vegetable oil types and packaged food categories with PCA–HCA

In this study, a total of 1380 packaged foods were examined, and it was determined that 50.1% of these foods contain palm oil according to the content information. This ratio is the highest compared to other vegetable oils. The second most abundant oil in packaged foods is sunflower oil (30.4%), which is the most produced in Türkiye. Other oils most commonly used are cocoa oil (17.6%), canola oil (16.4%), cottonseed oil (14.9%), and coconut oil (12.6%). Apart from these oils, the usage rates vary according to the categories of olive oil, butter, shea, flaxseed oil, soybean oil, hydrogenated oils, and corn oil are also used (Table 1).

Pearson correlation coefficients (PCC) were applied to determine whether there was a statistically significant relationship among the 11 categories of the research ($p < 0.05$ or $p < 0.01$). PCC is a correlation coefficient that measures the linear correlation between two datasets. It is the ratio between the covariance of two variables multiplied by their standard deviations. Therefore, the result always has a value between −1 and 1 (López-Gálvez et al., 2019). Statistical relationships and correlation coefficients concerning the edible oil content of packaged foods are shown in Table 2. The correlations were estimated by Row-wise method (de Vries, 1993). In general, it can be said that there is a correlation between packaged food categories. The high correlation between the ready-to-eat foods category (2) and spreads and sauces category (3) and between the chocolate and wafer category (7) and pastry ingredients category (5) is conspicuous. This situation also shows that PCC values are higher than others. However, contrary to this generalization, there is a statistically significant difference among the emulsified meat products category (9), pastry ingredients (5), and powdered drinks (11) categories. The PCCs value between these categories is statistically insignificant ($p > 0.05$).

Eigenvalue, percent variance values, and percent cumulative variance values are shown in Table 3. By using eigenvalues greater than one, sources of variance were selected as criteria to evaluate the PCs. The first two components, which are considered important according to

TABLE 1 Number and proportions of oil types listed in the contents of packaged foods (n = number of products).

Categories	Number of products examined		List of oil types												
			Palm oil		Sunflower oil		Canola oil		Cottonseed oil		Cocoa oil		Coconut oil		Other oils
	n	(%)	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	(*n*–%)
1	312	22.6	284	91	119	38.1	97	31.1	113	36.2	19	6.1	3	1	Butter (10–%3.2), shea (10–%3.2)
2	127	9.2	55	43.3	86	67.7	13	10.2	7	5.5	–	–	–	–	Olive oil (15–%11.8)
3	83	6	26	31.3	59	71.1	24	28.9	17	20.5	–	–	11	13.3	Hazelnut oil (5–%6), shea (5–%6)
4	21	1.5	17	81	15	71.4	16	76.2	13	61.9	–	–	7	33.3	Linseed oil (15–%71.4), safflower oil (2–%9.5)
5	53	3.8	24	45.3	1	1.9	5	9.4	–	–	13	24.5	6	11.3	Hydrogenated vegetable oil (23–%43.4)
6	117	8.5	24	20.5	12	10.3	18	15.4	5	4.3	–	–	–	–	Corn oil (10–%8.5)
7	221	16	126	57	25	11.3	13	5.9	21	9.5	131	59.3	32	14.5	Hydrogenated vegetable oil (27–%12.2), butter (23–%10.4), shea (18–%8.1)
8	87	6.3	62	71.3	25	28.7	20	23	22	25.3	36	41.4	58	66.7	Butter (38–%43.7), hydrogenated vegetable oil (3–%3.4)
9	127	9.2	3	2.4	29	22.8	–	–	–	–	–	–	–	–	Animal oil (113–%89)
10	189	13.7	58	30.7	48	25.4	20	10.6	7	3.7	44	23.3	24	12.7	Olive oil (17–%9), soybean oil (10–%5.3), butter (8–%4.2)
11	43	3.1	13	30.2	–	–	–	–	–	–	–	–	33	76.7	Hydrogenated vegetable oil (43–%100)
TOTAL	**1380**	**100**	**692**	**50.1**	**419**	**30.4**	**226**	**16.4**	**205**	**14.9**	**243**	**17.6**	**174**	**12.6**	

1. Bakery products category
2. Ready-to-eat foods category
3. Spreads and sauces category
4. Margarine and shortening category
5. Pastry ingredients category
6. Snacks category (chips, snacks, corn products)
7. Chocolate and wafer category
8. Ice cream category
9. Emulsified meat products category
10. Breakfast cereals, bars, baby food category
11. Powdered drinks category

TABLE 2 Pearson correlation coefficients between features of categories (*$p < 0.05$).

	1	2	3	4	5	6	7	8	9	10	11
1	1										
2	0.723	1									
3	0.667	0.910	1								
4	0.738	0.600	0.695	1							
5	0.727	0.369	0.231	0.374	1						
6	0.866	0.662	0.648	0.695	0.603	1					
7	0.588	0.319	0.192	0.232	0.911	0.398	1				
8	0.596	0.373	0.379	0.427	0.753	0.436	0.733	1			
9	0.348	0.871	0.867	0.402	−0.011*	0.334	0.061	0.152	1		
10	0.714	0.745	0.650	0.491	0.788	0.604	0.793	0.703	0.518	1	
11	0.177	0.056	0.114	0.211	0.420	0.103	0.278	0.691	−0.063*	0.340	1

1. Bakery products category
2. Ready-to-eat foods category
3. Spreads and sauces category
4. Margarine and shortening category
5. Pastry ingredients category
6. Snacks category
7. Chocolate and wafer category
8. Ice cream category
9. Emulsified meat products category
10. Breakfast cereals, bars, baby food category
11. Powdered drinks category

TABLE 3 Principal component analysis results.

	Eigenvalue	Variance (%)	Cumulative variance (%)
1	6.176	56.14	56.14
2	2.296	20.87	77.01
3	0.989	8.99	86.00
4	0.865	7.87	93.87
5	0.277	2.52	96.39
6	0.168	1.53	97.92
7	0.112	1.01	98.93
8	0.056	0.51	99.44
9	0.043	0.39	99.83
10	0.015	0.14	99.97
11	0.003	0.03	100

their eigenvalues, explain a large part of the total variance (71.01%). As seen in the summary plot graphics, if there is a 90° angle between the angles between the vectors, it is unlikely that there will be a correlation between the two vectors. For example, the pastry ingredients category (5)-chocolate and wafer category (7)-ice cream category (8) group has a 90° angle with the emulsified meat products category (9). In addition, the ready-to-eat foods category (2) and the spreads and sauces category (3) group made a 90° angle with the powdered drinks category (11). PCCs between these categories are also quite low. If there is a narrow angle between the vectors, there is a positive correlation between the two variables. For example, there are small angles between pastry ingredients category (5)-chocolate and wafer category (7)-ice cream category (8) and ready-to-eat foods category (2)-spreads and sauces category (3). PCCs between these categories are also quite high. As the angle between the vectors widens (closer to 180°), the variables have a negative correlation. For example, there is a wide angle between emulsified meat products category (9) and powdered drinks category (11) (Figure 1). PCCs between these categories are statistically significant ($p < 0.05$).

HCA is a technique used to obtain natural sets of objects in terms of their proximity in multidimensional space based on measured variables. The height of each branch point corresponds to the distance where two clusters meet. This is accomplished by finding a cutoff point (distance) where excessive branching is ignored. A number of different breakpoints can be tried to see which cutoff is more decisive. There are many methods available for clustering. Ward's method aims to find tight clusters by selecting

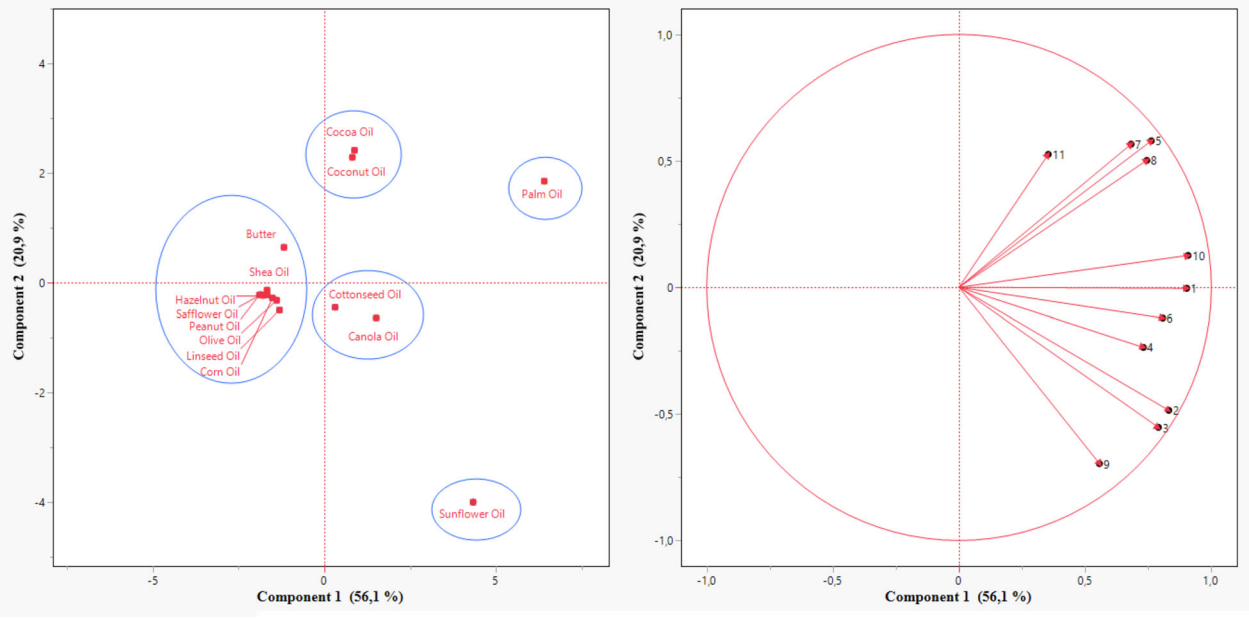

FIGURE 1 Summary plot graphics obtained from principal component analysis (PCA) data using edible oils usage rates.

clusters to be merged according to the change in cluster variances. Clusters are merged if the increase in combined variance over the sum of cluster-specific variances is minimal compared to alternative merging operations (Penn State Eberly College of Science, 2023). In this study, HCA was performed to reveal the differentiation of oils according to varieties. Figure 2 shows the dendrogram obtained from HCA, in which five main groups can be identified. The first group includes palm oil, the second group includes sunflower oil, and the third group includes canola and cottonseed oils, which are similar in terms of usage rates. In the fourth group, there are olive oil, soybean oil, shea oil, hazelnut oil, peanut oil, safflower oil, corn oil, butter, and linseed oil, which are similar in terms of their usage rates in packaged foods. The fifth group includes cocoa and coconut oils, which have similar usage rates. Although palm oil has the most widespread use in packaged foods as shown in the figure, sunflower oil, which is the most produced in Türkiye, is the second largest oil component. In this order, cotton and canola oils are followed by other oils according to the intensity of use. The last group includes cocoa and coconut oils, which are known to be more valuable oils.

3.2 | Types of oil contained in packaged foods according to categories

3.2.1 | Bakery products (biscuits, cake, crackers etc.) category

It was determined that 91% palm oil was used in the bakery products category containing 312 products in packaged foods. These ratios are diversified as 38.1% sunflower oil, 31.1% canola oil, 36.2% cottonseed oil, and 6.1% cocoa oil. As seen in the summary plot graphics, vector number 1 (bakery products) is closely connected to these oil types. There are many reasons why palm oil is used at such a high rate in bakery products. First of all, because palm oil is less costly than other vegetable oils, food manufacturers often prefer palm oil in bakery products. Palm oil is semisolid oil at room temperature because it contains a high percentage of unsaturated fatty acids. This provides the desired consistency and texture to the products when used in bakery products. Moreover, because palm oil is known to be resistant to oxidation, it can help bakery products stay fresh for a long time. For all these reasons, the rate of palm oil in the bakery category was quite high.

3.2.2 | Ready-to-eat foods (ready frozen products, ready soups, ready desserts, and canned foods) category

In the category of ready-to-eat foods, which includes 127 products in packaged foods, palm oil is used at a rate of 43.3%. These rates vary as 67.7% sunflower oil, 10.2% canola oil, 5.5% cottonseed oil, and 11.8% olive oil. It seems that the use of oils such as sunflower oil, which is rich in unsaturated fatty acids, is common among packaged foods in this category. In addition, it can be said that there is no need for oil types that will provide a viscous rheological feature when using these oils in foods in this category. In addition, as sunflower oil is the most produced oil in the country, it also has a cost advantage. As evident from the summary plots, vector number 2 (ready-to-eat foods) is closely

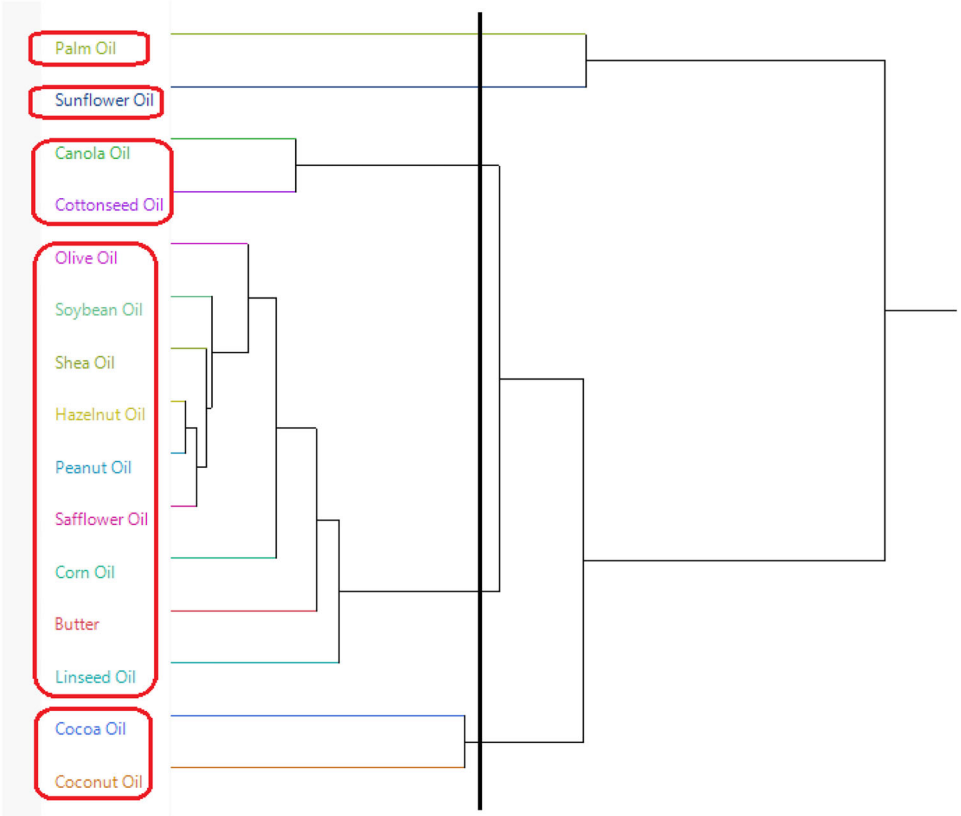

FIGURE 2 Hierarchical cluster analysis dendrogram of edible oils in packaged foods. The vertical line indicates the cut-off used to form the groups.

associated with different types of oils. The olive oil, which appears as an outlier in the graph, can be explained as being outside the scope of the first two PCs, which account for a substantial portion of the total variance (71.01%).

3.2.3 | Spreads and sauces category

In this category, which includes 83 products in packaged foods, 31.3% of palm oil is used. In this category, packaged foods also contain 71.1% sunflower oil, 28.9% canola oil, 20.5% cottonseed oil, 13.3% coconut oil, %6 hazelnut oil, and %6 shea oil. It is seen that the use of oils such as sunflower, canola, and cottonseed oils, which are rich in unsaturated fatty acids, is common in packaged foods in this category. In addition, it can be said that palm oil, which contains a certain amount of saturated fatty acids, is used together with oils rich in other unsaturated fatty acids in order to provide rheological properties in the spreadable foods in this category. In addition, as sunflower oil is the cheapest oil most produced in the country, its use is widespread. Based on the summary plot graphics, it is evident that vector number 3 (spreads and sauces category) exhibits a close association with these oil types. The outliers observed in the graph, hazelnut oil, and shea oil are generally used in low proportions. Therefore, it can be explained that the scope of the first two PCs, which collectively account for a significant portion of the total variance (71.01%), may not encompass these outliers.

3.2.4 | Margarine and shortening category

The content of 21 products in the margarine and shortening category contains 81% palm oil. In this category, packaged foods were also determined to be 71.4% sunflower oil, 76.2% canola oil, 61.9% cottonseed oil, 33.3% coconut oil, 71.4% linseed oil, and 9.5% safflower oil. Packaged foods in this category must use oils rich in both saturated and unsaturated fatty acids. That's why the usage rates of edible oil types are generally high. As seen in the summary plot graphics, vector number 4 (margarine and shortening category) is closely connected to these oil types. As observed in the summary plot graph, despite their high usage rates, linseed oil and relatively low usage rate of safflower oil appear disconnected from vector number 4 in the graph. This could be attributed to the fact that the scope of the first two PCs, which collectively explain a significant portion of the total variance (71.01%), does not encompass these oils.

3.2.5 | Pastry ingredients category

There is 45.3% palm oil in the content of 53 products in the Pastry ingredients category. Packaged foods in this category also contain 1.9% sunflower oil, 9.4% canola oil, 24.5% cocoa oil, and 11.3% coconut oil. Hydrogenated vegetable oil expression is used in 43.4% of the products in this category. Oils rich in saturated fatty acids are preferred in packaged foods in this category. Therefore, it is expected that the palm oil content is high. Additionally, the use of hydrogenated oils is common in foods in this category, and this is reflected in the rate of use. Based on the summary plot graphics, it is evident that vector number 5 (pastry ingredients category) exhibits a close association with these types of oils. Due to the high usage rates of palm, coconut, and cocoa oils in the products in this category, there is a high correlation with these oils, as seen in the summary plot. Hydrogenated vegetable oil was not included in the PCA analysis because the oil type was not specified in the products in this category.

3.2.6 | Snacks category (chips, snacks, and corn products)

There is 20.5% palm oil in the content of 117 products in the snacks category. Packaged foods in this category also contain 10.3% sunflower oil, 15.4% canola oil, 4.3% cotton oil, and 8.5% corn oil. There is generally a tendency to reduce the fat content in packaged products in this category due to consumer expectations. Oil types containing both saturated and unsaturated fatty acids can be used in the oil content of these products, where food processing methods such as frying are generally used. Based on the summary plot graphics, it can be observed that vector number 6 (snacks category) is closely associated with these oil types. It can be asserted that corn oil, which is perceived as an outlier in the summary plot graph, lies outside the scope of the first two PCs that account for a significant portion of the total variance (%71.01).

3.2.7 | Chocolate and wafer category

The content of 221 products in the chocolate and wafer category contains 57% palm oil. Packaged foods in this category also contain 11.3% sunflower oil, 5.9% canola oil, 9.5% cottonseed oil, 59.3% cocoa, and 14.5% coconut oil. It is seen that 12.2% of the products in this category contain hydrogenated vegetable oil, 10.4% butter and 8.1% shea butter. The use of oils with high unsaturated fatty acid content in packaged food products in this category is not suitable in terms of the rheological properties expected from chocolate products. That's why oils with high saturated fat content, such as palm and cocoa oil, are mostly preferred. As cocoa oil is expensive oil, alternative oils such as hydrogenated and coconut oils can be used. As seen in the summary plot graphics, vector number 7 (chocolate and wafer category) is closely connected to these oil types. Vector number 7 was among palm and cocoa oils, which have a high rate of use. This indicates that this vector has a high correlation with these oils. It can be said that butter and shea butter, which appear as outliers in the Summary plot, are outside the scope of the first two PCs that explain a significant part of the total variance (71.01%). Hydrogenated vegetable oil was not included in the PCA analysis because the oil type was not specified in the products in this category.

3.2.8 | Ice cream category

Palm oil is used in 71.3% of 87 products in the ice cream category. Packaged foods in this category contain 28.7% sunflower oil, 23% canola oil, 25.3% cottonseed oil, 41.4% cocoa, and 66.7% coconut oil. Products in this category also contain 43.7% butter and 3.4% hydrogenated vegetable oil. Oils with high saturated fatty acid content are preferred in packaged foods in this category. Although butter usage rate is high, it is an expensive oil source and palm and coconut oils are preferred in industrial production. Cocoa oil content is also used in high amounts in chocolate products as it is important in terms of rheological properties. As evident from the summary plot graphics, vector number 8 (ice cream category) exhibits a close association with these oil types. Vector number 8 was among the high usage rates of palm, cocoa, and coconut oils. This indicates that this vector has a high correlation with these oils. It can be said that butter, which appears as an outlier in the summary plot, is outside the scope of the first two PCs that explain a significant part of the total variance (71.01%). Hydrogenated vegetable oil was not included in the PCA analysis because the type of oil was not specified in the products in this category.

3.2.9 | Emulsified meat products category

Palm oil is used in 2.4% of 127 packaged products in this category. In this category, sunflower oil constitutes 22.8% of the content (excluding 2.4% palm oil) and does not contain other types of oils. As expected, packaged foods in this category have high animal fat content. It is seen that sunflower oil is used in products such as sausages and salami.

As observed in the summary plot graph, vector number 9 (emulsified meat products category) exhibits correlation exclusively with sunflower oil. As anticipated in this category, the content of animal oil is notably high (89%). However, these two types of oils were not included in the PCA analysis.

3.2.10 | Breakfast cereals, bars, and baby food category

Palm oil is used in 30.7% of 189 packaged products in the breakfast cereals, bars, and baby food category. It was determined that packaged foods in this category contain 25.4% sunflower oil, 10.6% canola oil, 3.7% cottonseed oil, 23.3% cocoa, and 12.7% coconut oil. It is also observed that 9% of the products in this category contain olive oil, 5.3% contain soybean oil, and 4.3% contain butter. The product variety in packaged foods in this category is quite high. Therefore, there is no dominance of a certain type of oil. In addition to cocoa butter, which is mainly used in chocolate products, palm oil is widely used. It can be said that the use of coconut and sunflower oils is also common. As evident from the summary plot graph, vector number 10 (breakfast cereals, bars, and baby food category) displays a close correlation with the listed oil types. Furthermore, vector number 10 is positioned contrary to olive oil, soybean oils, and butter in the summary plot graph. It can be said that these oils fall outside the scope of the first two PCs, which account for a significant portion of the total variance (71.01%). Additionally, this category exhibits close correlations with categories 1 (bakery products category), 5 (pastry ingredients category), 7 (chocolate and wafer category), and 8 (ice cream category), indicating a consistency in the types of oils used.

3.2.11 | Powdered drinks category

It was determined that 30.2% of 43 packaged products in the category of powdered drinks contain palm oil. It is seen that the content of packaged foods in this category contains 76.7% coconut, as well as 100% hydrogenated vegetable oil. As seen in the summary plot, vector number 11 (powdered drinks category) shows a close correlation with palm, coconut, and cocoa oils. Although the products in this category do not contain cocoa oil, they are positioned as if there is a correlation in the summary plot. According to the data contrary to the summary plot, it can be said that cocoa oil is outside the scope of the first two PCs, which explain a significant part of the total variance (71.01%). Hydrogenated vegetable oil was not included in the PCA analysis because the oil type was not specified in the products in this category. As the packaged foods in this category are mostly coffee products, the rate of use of fully hydrogenated vegetable oil is noteworthy. In addition, the usage rates of palm and coconut oils, which are rich in saturated fatty acids, are also high. Other oils are not used in this category due to their high unsaturated fatty acid content.

4 | CONCLUSION

According to the obtained data, it is observed that packaged foods, categorized into 11 groups, contain different types of oils in varying proportions based on quality expectations. Particularly, the use of vegetable oils that mimic the functional properties imparted to foods by partially hydrogenated vegetable oils, which are a significant source of TFAs, has become widespread. Among these oils, palm oil, rich in saturated and unsaturated fatty acids, stands out. Specifically, products such as bakery products, ready-to-eat foods, spreads and sauces, pastry ingredients, and ice creams are produced with high contents of palm oil. Similarly, sunflower, canola, and cottonseed oils, which are rich in unsaturated fatty acids, are commonly used in bakery goods, ready-to-eat foods, spreads and sauces, margarine, and shortening products. Cocoa oil, a valuable fat, is frequently used in chocolate and wafer products, as well as ice creams, as expected. Coconut oil, an important alternative fat, has been found to be used in high proportions in ice creams and powdered drinks products. Furthermore, fully hydrogenated vegetable oils are also highly used in products where a high content of saturated fatty acids is required, such as pastry ingredients, chocolate and wafer products, ice creams, and powdered drinks. In summary, it is essential for manufacturers to clearly declare the oil contents in packaged foods and optimize the usage of oils, taking into consideration consumer health expectations. In line with recent global policies aimed at eliminating TFAs in packaged foods, further research efforts related to the oil content in such products should be supported.

The health expectations of consumers continuously keep the variety and usage ratios of vegetable oils in focus, as producers tend to manufacture products with reduced standard costs. Through such studies and similar endeavors, an inventory of the types of oils offered for consumption by individuals in each country can be compiled. If legal regulations are deemed necessary concerning the consumption of palm oil and/or different vegetable oils based on consumer health expectations, and if there is a need for the development of policies related to the requirement for alternative vegetable oil varieties in the content of packaged food products (interesterification, fractionation, and oleogelation), this study has the potential to serve as a valuable resource.

AUTHOR CONTRIBUTIONS

Necattin Cihat Icyer: Conceptualization; writing—original draft; methodology; validation; visualization; writing—review and editing. **Nesrin Kuran**: Investigation; writing—original draft; data curation; methodology.

CONFLICT OF INTEREST STATEMENT

The authors declared that they have no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data can be shared upon request.

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REFERENCES

Akkaya, M. R. (2018). Prediction of fatty acid composition of sunflower seeds by near-infrared reflectance spectroscopy. *Journal of Food Science and Technology*, *55*(6), 2318. https://doi.org/10.1007/S13197-018-3150-X

Penn State Eberly College of Science. (2023). *Applied multivariate statistical analysis*. The Pennsylvania State University. https://online.stat.psu.edu/stat505/book

Barthet, V. J. (2016). Canola: Overview. *Encyclopedia of Food Grains: Second Edition*, *1–4*, 237–241. https://doi.org/10.1016/B978-0-12-394437-5.00029-2

Boateng, L., Ansong, R., Owusu, W., & Steiner-Asiedu, M. (2016). Coconut oil and palm oil's role in nutrition, health and national development: A review. *Ghana Medical Journal*, *50*(3), 189. https://doi.org/10.4314/gmj.v50i3.11

Borrello, M., Annunziata, A., & Vecchio, R. (2019). Sustainability of palm oil: Drivers of consumers' preferences. *Sustainability*, *11*(18), 4818. https://doi.org/10.3390/SU11184818

Capecchi, S., Amato, M., Sodano, V., & Verneau, F. (2019). Understanding beliefs and concerns towards palm oil: Empirical evidence and policy implications. *Food Policy*, *89*, 101785. https://doi.org/10.1016/J.FOODPOL.2019.101785

de Vries, H. (1993). The rowwise correlation between two proximity matrices and the partial rowwise correlation. *Psychometrika*, *58*(1), 53–69. https://doi.org/10.1007/BF02294470/METRICS

Diomandé, D., Dro, T. T., Akpa, J. S., Virginie, S., Tea, I., & Remaud, G. S. (2022). Quantitative measurement of the chemical composition of fatty acid of cocoa butter and the isotopic content of glycerol contained in cocoa butter by the NMR 13C from the INEPT sequence and characterization of the geographical origin of the cocoa. *American Journal of Analytical Chemistry*, *13*(3), 79–95. https://doi.org/10.4236/AJAC.2022.133007

Disdier, A.-C., Marette, S., & Millet, G. (2013). Are consumers concerned about palm oil? Evidence from a lab experiment. *Food Policy*, *43*, 180–189. https://doi.org/10.1016/J.FOODPOL.2013.09.003

Fattore, E., & Fanelli, R. (2013). Palm oil and palmitic acid: A review on cardiovascular effects and carcinogenicity. *International Journal of Food Sciences and Nutrition*, *64*(5), 648–659. https://doi.org/10.3109/09637486.2013.768213

Gesteiro, E., Guijarro, L., Sánchez-Muniz, F. J., Vidal-Carou, M. D. C., Troncoso, A., Venanci, L., Jimeno, V., Quilez, J., Anadón, A., & González-Gross, M. (2019). Palm oil on the edge. *Nutrients*, *11*(9), 2008. https://doi.org/10.3390/nu11092008

Kanter, R., Reyes, M., & Corvalán, C. (2017). Photographic methods for measuring packaged food and beverage products in supermarkets. *Current Developments in Nutrition*, *1*(10), e001016. https://doi.org/10.3945/cdn.117.001016

Kellens, M., & Calliauw, G. (2013). Oil modification processes. In *Edible oil processing* (pp.153–196). John Wiley & Sons, Inc. https://doi.org/10.1002/9781118535202.CH6

López-Gálvez, F., Tudela, J. A., Allende, A., & Gil, M. I. (2019). Microbial and chemical characterization of commercial washing lines of fresh produce highlights the need for process water control. *Innovative Food Science & Emerging Technologies*, *51*, 211–219. https://doi.org/10.1016/J.IFSET.2018.05.002

Martin, C. A., Milinsk, M. C., Visentainer, J. V., Matsushita, M., & De-Souza, N. E. (2007). Trans fatty acid-forming processes in foods: A review. *Anais da Academia Brasileira de Ciencias*, *79*(2), 343–350. https://doi.org/10.1590/S0001-37652007000200015

Menaa, F., Menaa, A., Menaa, B., & Tréton, J. (2013). Trans-fatty acids, dangerous bonds for health? A background review paper of their use, consumption, health implications and regulation in France. *European Journal of Nutrition*, *52*(4), 1289–1302. https://doi.org/10.1007/s00394-012-0484-4

Pase, C. S., Metz, V. G., Roversi, K., Roversi, K., Vey, L. T., Dias, V. T., Schons, C. F., de David Antoniazzi, C. T., Duarte, T., Duarte, M., & Burger, M. E. (2021). Trans fat intake during pregnancy or lactation increases anxiety-like behavior and alters proinflammatory cytokines and glucocorticoid receptor levels in the hippocampus of adult offspring. *Brain Research Bulletin*, *166*, 110–117. https://doi.org/10.1016/j.brainresbull.2020.11.016

Plasek, B., Lakner, Z., Badak-Kerti, K., Kovács, A., & Temesi, Á. (2021). Perceived consequences: General or specific? The case of palm oil-free products. *Sustainability*, *13*(6), 3550. https://doi.org/10.3390/SU13063550

Ricardo, C. Z., Peroseni, I. M., Mais, L. A., Martins, A. P. B., & Duran, A. C. (2019). Trans fat labeling information on Brazilian packaged foods. *Nutrients*, *11*(9), 2130. https://doi.org/10.3390/nu11092130

Savarese, M., Castellini, G., Paleologo, M., & Graffigna, G. (2022). Determinants of palm oil consumption in food products: A systematic review. *Journal of Functional Foods*, *96*, 105207. https://doi.org/10.1016/J.JFF.2022.105207

Shahidi, F. (2005). *Bailey's industrial oil and fat products*. John Wiley & Sons, Inc.

Statista. (2023). *Vegetable oils: Global consumption 2022/23*. Statista. https://www.statista.com/statistics/263937/vegetable-oils-global-consumption/

Stender, S., & Jorn, D. (2006). High levels of industrially produced trans fat to the editor : The daily intake of about 5 g of. *Journal Of The American Oil Chemists Society*, *354*(15), 1650–1652.

Sulaiman, N. S., Sintang, M. D., Mantihal, S., Zaini, H. M., Munsu, E., Mamat, H., Kanagaratnam, S., Jahurul, M. H. A., & Pindi, W. (2022). Balancing functional and health benefits of food products formulated with palm oil as oil sources. *Heliyon*, *8*(10), e11041. https://doi.org/10.1016/J.HELIYON.2022.E11041

Temkov, M., & Mureşan, V. (2021). Tailoring the structure of lipids, oleogels and fat replacers by different approaches for solving the trans-fat issue—A review. *Foods*, *10*(6), 1376. https://doi.org/10.3390/foods10061376

Van Duijn, G. (2005). Technical aspects of trans reduction in modified fats. *OCL—Oilseeds and fats, Crops and Lipids*, *12*(5–6), 422–426. https://doi.org/10.1051/ocl.2005.0422

Verneau, F., Barbera, F. L., Amato, M., & Sodano, V. (2019). Consumers' concern towards palm oil consumption an empirical study on attitudes and intention in Italy. *British Food Journal*, *121*(9), 1982–1997. https://doi.org/10.1108/BFJ-10-2018-0659/FULL/PDF

Verneque, B. J. F., Machado, A. M., De Abreu Silva, L., Lopes, A. C. S., & Duarte, C. K. (2020). Ruminant and industrial trans-fatty acids consumption and cardiometabolic risk markers: A systematic review. *Critical Reviews in Food Science and Nutrition*, *62*(8), 2050–2060. https://doi.org/10.1080/10408398.2020.1836471

Walsh, M. K. (2007). Immobilized enzyme technology for food applications. In *Novel enzyme technology for food applications* (pp. 60–84). Woodhead Industries.https://doi.org/10.1533/9781845693718.1.60

Wassmann, B., Siegrist, M., & Hartmann, C. (2023). Palm oil and the roundtable of sustainable palm oil (RSPO) label: Are Swiss consumers aware and concerned? *Food Quality and Preference*, *103*, 104686. https://doi.org/10.1016/J.FOODQUAL.2022.104686

Yang, A., Qi, M., Wang, X., Wang, S., Sun, L., Qi, D., Zhu, L., Duan, Y., Gao, X., Ali Rajput, S., & Zhang, N. (2019). Refined cottonseed oil as a replacement for soybean oil in broiler diet. *Food Science & Nutrition*, *7*(3), 1027. https://doi.org/10.1002/FSN3.933

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