RESEARCH ARTICLE

Data mining to map the nutrition value of industrial cheese produced in France

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Abstract: Cheese is a dairy product with a long history in the human diet. In countries such as France, cheese is one of the strongest attractions for visitors from around the globe. The cheese was thought of as only a source of energy alone; however, with advances in nutritional science, cheese has become a rich source of essential nutrients such as proteins, bioactive peptides, amino acids, vitamins and minerals. This perspective offers new insights into the nutrition analysis of various types of cheese sold in France, using advanced data visualization and analysis techniques. This article aims to raise awareness about making an informed selection of the type of cheese people should consume as a long-term measure of taking a health-conscious diet. Overall, the study provides a testbed for turophiles (cheese lovers) in selecting the right kind of cheese to relish themselves while taking care of their health condition depending on their physical condition, particularly lactose intolerance.
Keywords: data, nutrition; cheese.

1. INTRODUCTION

The word 'cheese' originated from the Latin word 'caseus' (Johnson, 2017). It is believed that the art of making cheese came into being about 8000 years ago (Beresford *et al.*, 2001), and by now, more than 2000 cheese varieties are reported, prepared mainly by coagulation of milk by chymosin, and matured between 2 weeks and two years (Feeney *et al.*, 2021). Among "ricotta", "gouda", "parmesan", "Roquefort", "brie", "stilton", "cheddar", "camembert" and others, "mozzarella" continues to be the most popular cheese across the world, as its daily consumption in most types of pizza, pasta and others is growing (Salque *et al.*, 2013). The global cheese market is estimated to be about $100 bn, and global cheese consumption is expected to increase by ~13.8% between 2019 and 2029 (Feeney *et al.*, 2021). Cheeses are rich in nutrients and are a significant source of high-quality proteins, lipids, vitamins (e.g. vitamins B2, A and B12) and minerals such as calcium and phosphorus (Ermolaev, Yashalova, & Ruban, 2019). However, cheese also contains high levels of saturated fatty acids (SFAs), which are commonly perceived as negatively impacting the healthfulness of the diet, and have been associated with increased blood low-density lipoprotein cholesterol (LDL) levels which presents the risk of cardiovascular disease (CVD) and much work in this area is currently under intensive investigation (O'Brien & O'Connor, 2017).

Cheese is produced using a complex milk processing pathway. The process begins with the coagulation of milk through enzymes or using an acid treatment leading to obtaining semi-solid curds (a

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combination of the significant milk nutrients —protein, mainly casein, and milk fat) (Feeney *et al.*, 2021). It then requires removing water-soluble lactose by straining off the liquid whey. The straining process is commonly achieved using a coarse textile, 'cheesecloth', or plastic or metal sieves (Salque *et al.*, 2013).

Extensive need for functionality, taste, application in baking, and nutritional aspects (low fat and low sodium) of cheese presents a strong necessity to understand the fundamental principles of cheese making, which in turn requires advanced scientific investigations into the chemical, microbiological, and enzymatic changes involved in the cheese-making process (Johnson, 2017).

There are two types of cheese: Natural cheese and Process cheese. Natural cheese is made from four main ingredients: milk, rennet, microorganisms and salt, which are processed through several common steps such as gel formation, whey expulsion, acid production and salt addition, followed by a period of ripening. While all acid-coagulated cheeses are consumed fresh, most rennet-coagulated cheese undergoes a period of ripening which can range from about three weeks for Mozzarella to two years or more for Parmesan and extra-mature Cheddar. On the other hand, Process cheese requires natural cheese as the raw material. Process cheese is produced by blending natural cheese of different ages and degrees of maturity in the presence of emulsifying salts and other dairy and non-dairy ingredients, followed by heating and continuous mixing to form a homogeneous product with an extended shelf life (Kapoor *et al.*, 2008). The three major types of processed cheese described by the Code of Federal Regulations (CFR) are (a) pasteurized process cheese (PC), (b) pasteurized process cheese food (PCF) and (c) pasteurized process cheese spread (PCS).

Cheese is now *internationally* known as a tourism attraction (gastronomic, culinary) and promotes tourism as people from all over the world travel 1000s of miles to taste a variety of cheese products. Thus, the exploitation of cheese by the tourism industry contributes to sustainability, supporting rural lifestyles and facilitating the integration of rural traditions, heritage, and natural landscapes (Ermolaev *et al.*, 2019).

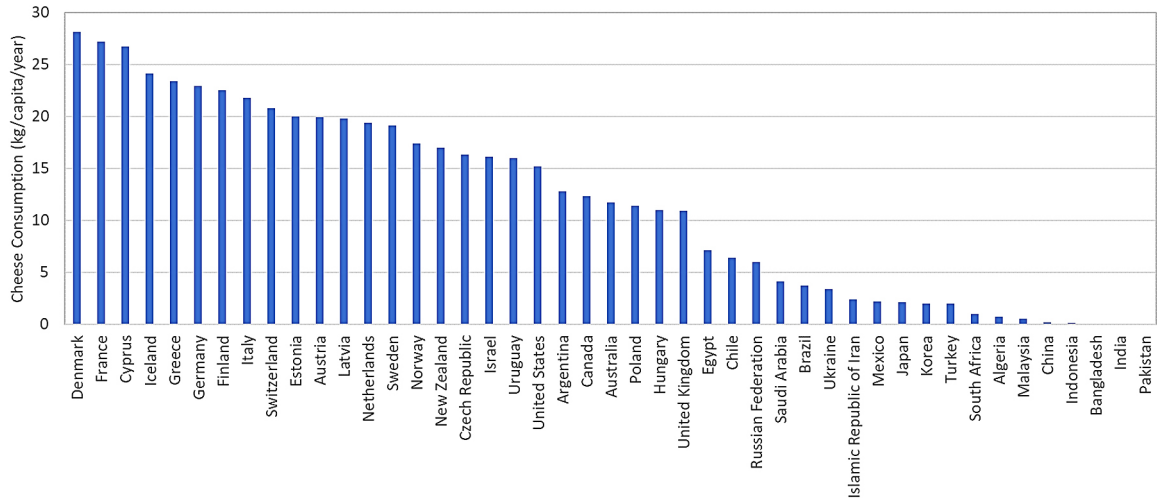


Figure 1. Global cheese consumption concerning individual countries (authors' original plot)

Fig. 1 highlights the global consumption of cheese in every country. It may be seen that European countries such as Denmark, France, Cyprus, Iceland, Greece, Germany, Finland and Italy are among the top cheese-consuming countries, while countries such as India, Pakistan, China, Bangladesh and Indonesia are on the other side of the scale where cheese consumption is deficient. A plausible reason for this has been pointed out by (Feeney *et al.*, 2021) in their recent review that there are perceived health risks with excessive cheese consumption. The study by (Feeney *et al.*, 2021) highlighted that although the preventing measure for cardiovascular disease risk is to limit the intake of saturated fat consumption due to adverse associations with low-density lipoprotein cholesterol (LDL), this advice does not account for the diversity of fatty acids present in dairy foods and cheese, whereby the

combinatorial presence of various components present within the food could instead lead to health benefits (Johnson, 2017). Cholesterol and saturated fat are potential risk factors for atherosclerosis, and besides fat, the calcium-magnesium ratio, lactose and milk fat globule membrane antigens may also have specific coronary atherogenic effects (Ropars *et al.*, 2012). However, other components may reduce risks, for example, conjugated linoleic acid (CLA), which have antioxidant and anticancer properties, as well as calcium which can protect against hypertension and osteoporosis, and the presence of folic acid, vitamin B6, and vitamin B12 can provide beneficial effects on plasma homocysteine level (an independent risk factor for atherosclerosis) (O'Brien & O'Connor, 2017).

These vital ingredients in cheese can adversely affect health, while some are supportive of health. This contradiction opens the possibility of reexamining and analysing varieties of cheese, which was the primary motivation of this paper.

Moreover, lactose intolerant individuals (who have inadequate production of the lactase enzyme to digest lactose) may have difficulty digesting fresh milk. Still, they can eat certain dairy products, such as cheese or yogurt without any problems. This is due to the fermentation processes involved in cheese preparation, which breaks down a high percentage of lactose compared to fresh milk (Beresford *et al.*, 2001). Therefore, cheese can be an excellent candidate to replace dairy milk for those who are not fully lactose intolerant (Beresford *et al.*, 2001). Furthermore, these days lactose-free milk can be used to make cheese for fully lactose-intolerant individuals. A list of lactose content (g) per 100 g of milk and derivatives is tabulated in the study by (Facioni *et al.*, 2020). Still, a detailed description of all nutrients in worldwide popular cheese is essential for consumers to make the right choice.

Through this paper, our ambition was to provide clarity to those individuals who perceive cheese negatively and avoid consuming it. This is especially crucial for Asia, given the imminent food security challenge in the wake of climate change. We performed intensive data analysis to understand the hidden nutritional value in the cheese using extensive data collection of market cheese products to help consumers to choose the right cheese to support their needs.

2. RESEARCH METHODOLOGY

To examine the nutrition value of various cheese products concerning their nutrition score, energy content, fat/saturated fat content, cholesterol, carbohydrates, sugar/fiber, protein, and salts content per 100 g of cheese, a data-mining approach was adopted with the support of the Python 3.9 platform. This study used the dataset collected from an open-source database (See Data statement). This dataset contained different categories of cheese, which were grouped into five different grades (a, b, c, d and e) based on their nutritional value. Also, the dataset contains eleven qualitative variables (additives, nutriscore_score, energy-kcal_100 g (energy in kcal in per 100 g of cheese), fat_100 g, saturated-fat_100 g, cholesterol_100 g, carbohydrates_100 g, sugars_100 g, fiber_100 g, proteins_100 g, salt_100 g).

Table 1. List of variables and their corresponding number of instances that are analyzed in this study.

Variables	Description of used variables	Available data
nutriscore_grade	Nutrition grade	11943
additives_n	Number of added additives	10368
nutriscore_score	Nutrition score	11557
energy-kcal_100 g	Energy content (kcal) in per 100 g of cheese	12169
fat_100 g	Fat content (kcal) in per 100 g of cheese	8461
saturated-fat_100 g	Saturated fat content (kcal) in per 100 g of cheese	2275
cholesterol_100 g	Cholesterol content (kcal) in per 100 g of cheese	1435
carbohydrates_100 g	Carbohydrates content (kcal) in per 100 g of cheese	12218
sugars_100 g	Sugar content (kcal) in per 100 g of cheese	12030
fiber_100 g	Fiber content (kcal) in per 100 g of cheese	11077
proteins_100 g	Protein content (kcal) in per 100 g of cheese	4454
salt_100 g	Salt content (kcal) in per 100 g of cheese	9578

Table 1. Describes all these variables present in the dataset and their corresponding number of instances. It can be noted that data is missing for some of the variables.

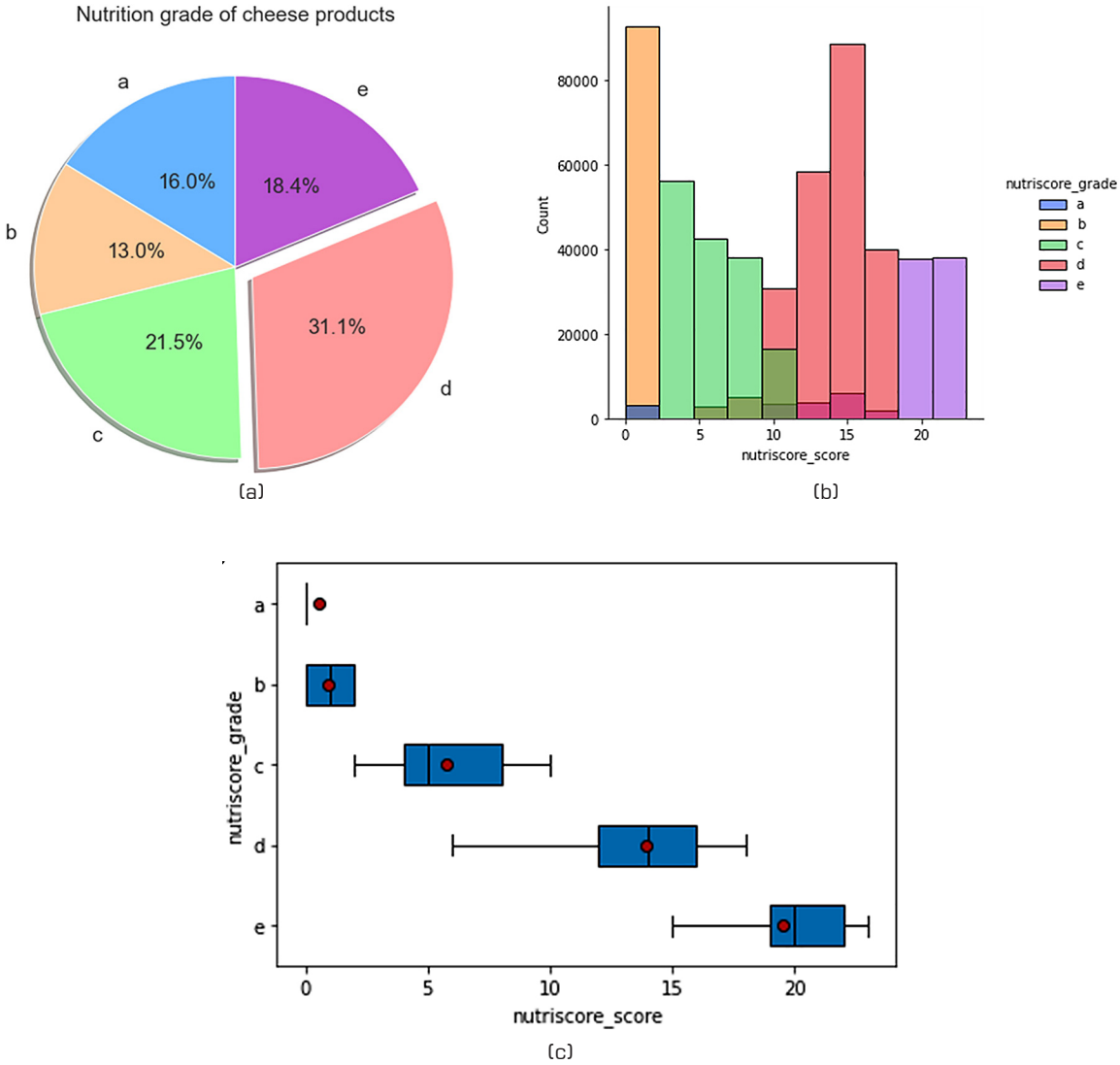


Figure 2. Complete data description (a) pie chart showing the percentage of data belonging to each nutrition grade of cheese products, (b) bar chart showing the correlation of nutrition grade to the nutrition score, (c) boxplot between nutrition score and nutrition grade in different cheese products.

Furthermore, to get better insights into complete data, matplotlib and seaborn libraries in python were used to visualise and analyse data. A pie chart shown in Fig. 2(a) represents the percentage of data corresponding to five different grades of cheese. The highest instances of cheese correspond to nutrition grade 'd' (31.1%), while grade b (13.0%) contained the least instance of cheese. Fig. 2(b) demonstrates a bar chart representing the nutrition score as per different nutrition grades of cheese. A box plot between nutrition score and nutrition grade for a variety of cheese is shown in Fig. 2(c). One can see that the better the nutrition grade (towards a), the smaller the nutrition score (in the range of 1-2 for grade a cheese), while the nutrition score is quite high for grades 'd' and 'e' cheese types.

3. RESULT AND DISCUSSIONS

To observe the correlation between different qualitative variables, a correlation matrix is presented in Fig. 3. It can be observed that some groups of nutrients are well correlated, for example, nutrition score vs salt, nutrition score vs energy, nutrition score vs saturated fat, nutrition score vs fat and carbohydrates vs sugar. The number of additives was seen to correlate with sugar and carbohydrate content per 100 g of cheese.

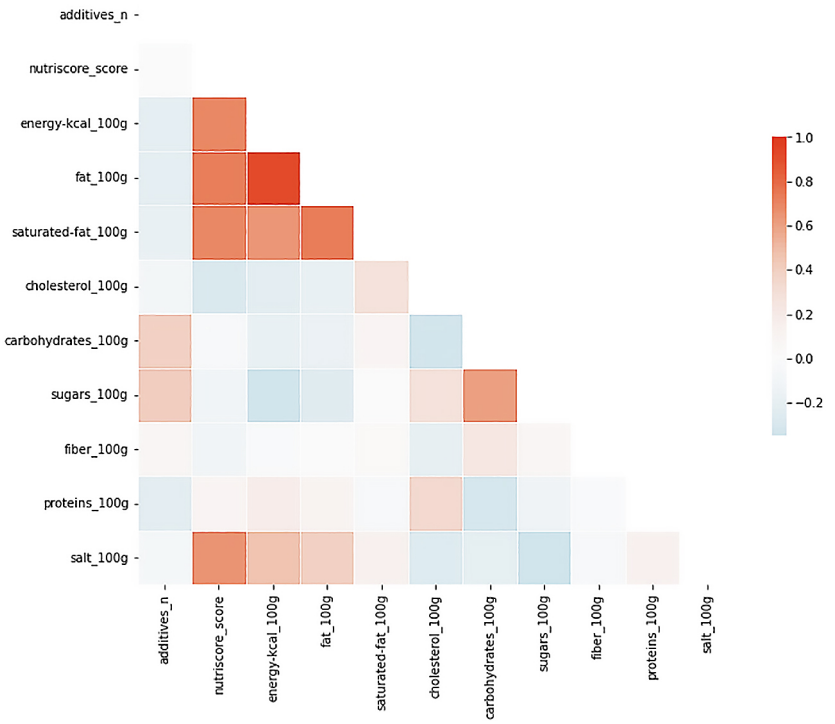


Figure 3. Correlation matrix of the nutrients in cheese products per 100 g

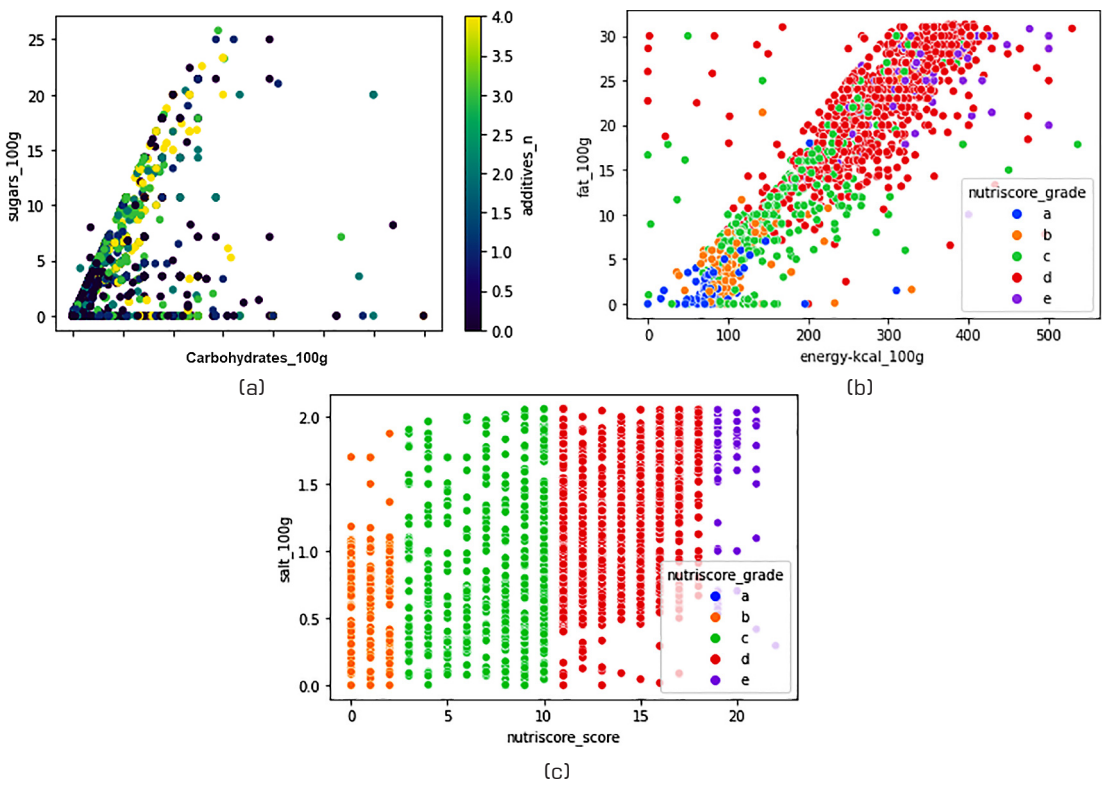


Figure 4. Scatter plot showing (a) sugars vs carbohydrates about several additives, (b) fat vs energy content per 100 g of cheese for different grades of cheese, (c) Salt vs nutrition score for different grades of cheese.

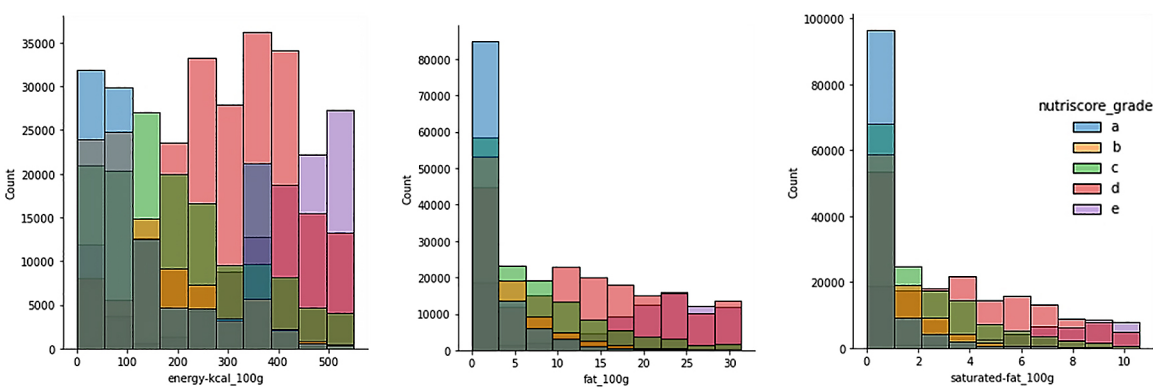
Furthermore, the relation between sugars and carbohydrates concerning the number of additives is highlighted in Fig. 4(a). It is well known that carbohydrates are linearly correlated to sugars. Still, surprisingly these were also seen related to the number of additives such that more sugars and carbohydrates showed a positive correlation with the additives. A linear correlation between the amount of fat and energy in cheese products for every 100 g of cheese was also noticed, which is demonstrated in Fig. 4(b). The higher grades cheese types (a and b) tend to have lower fat and energy content, contrary to lower grades cheese types (d and e).

Fig. 4(c) presents the nutrition score concerning salt for all five grades of cheese. It shows a linear relationship between the amount of salt and the nutrition score; a product with a higher amount of salt tends to have a higher nutrition score.

The distribution of different nutrients in cheese products is presented in Fig. 5. The interesting fact here is that most of the cheese products in this dataset have energy content ranging from 0 to 550 kcal, fat in the range of 0 to 32 g, saturated fat in the range of 0 to 12 g, cholesterol in the range of 0 to 0.035 g, carbohydrates in the range of 0 to 75 g, sugar in the range of 0 to 27 g, the fiber in the range of 0 to 8 g, protein in the range of 0 to 18 g, and salt in the range of 0 to 2 g per 100 g of cheese for five different grades of cheese.

Although the fat content of cheese varies considerably depending on the milk used and the method of manufacture, it is recommendable by experts worldwide to reduce the intake of both total and saturated fat (Johnson, 2017). In this study, grade cheese was found to contain lowertotal fat and saturated fat content per 100 g of cheese, as shown in Fig. 5(b) and Fig. 5(c), respectively. The cholesterol content of cheese is a function of its fat content, which can be observed in Fig. 5(d). It shows that the lower grade cheese *d* and *e* showed higher levels of cholesterol per 100 g of cheese, as the fat content of these grades of cheese is much higher than the cheese of grade *a* and grade *b*. Furthermore, it is well known that approximately 70% of the global adult population are lactose intolerant; therefore, lower carbohydrate-content cheeses are in demand (Fox *et al.*, 1996). Although during cheese manufacturing, only trace amounts of carbohydrates remain. Still the lower grade cheese (grade d and grade e) can be observed to contain higher carbohydrates per 100 g of cheese, as shown in Fig. 5(e). Thus, grade a and b cheese types can be consumed without ill effects by lactose-intolerant individuals who are deficient in the intestinal enzyme, β-galactosidase. Sugar content per 100 g of cheese was found higher for grade 'd' cheese, as shown in Fig. 5(f).

Cheese contains a high level of biologically valuable protein and fiber. The protein/fiber content of different cheeses tends to vary inversely with fat content (O'Brien & O'Connor, 2017), which is shown in Fig. 5(b), Fig. 5(g) and Fig. 5(h). It can be observed that higher-grade cheese (type a and b) contains much higher protein and fiber per 100 g of cheese compared to lower-grade cheese (type d and e). Both sugar and salt are observed to be on the higher side in the low-grade types of cheese (grade d and grade e). This study alluded to the fact that the higher-grade cheese type a and type b are healthier than other cheese types, and they must be preferred as a healthier diet option considering the growing worldwide health issues.



(a) (b) (c)

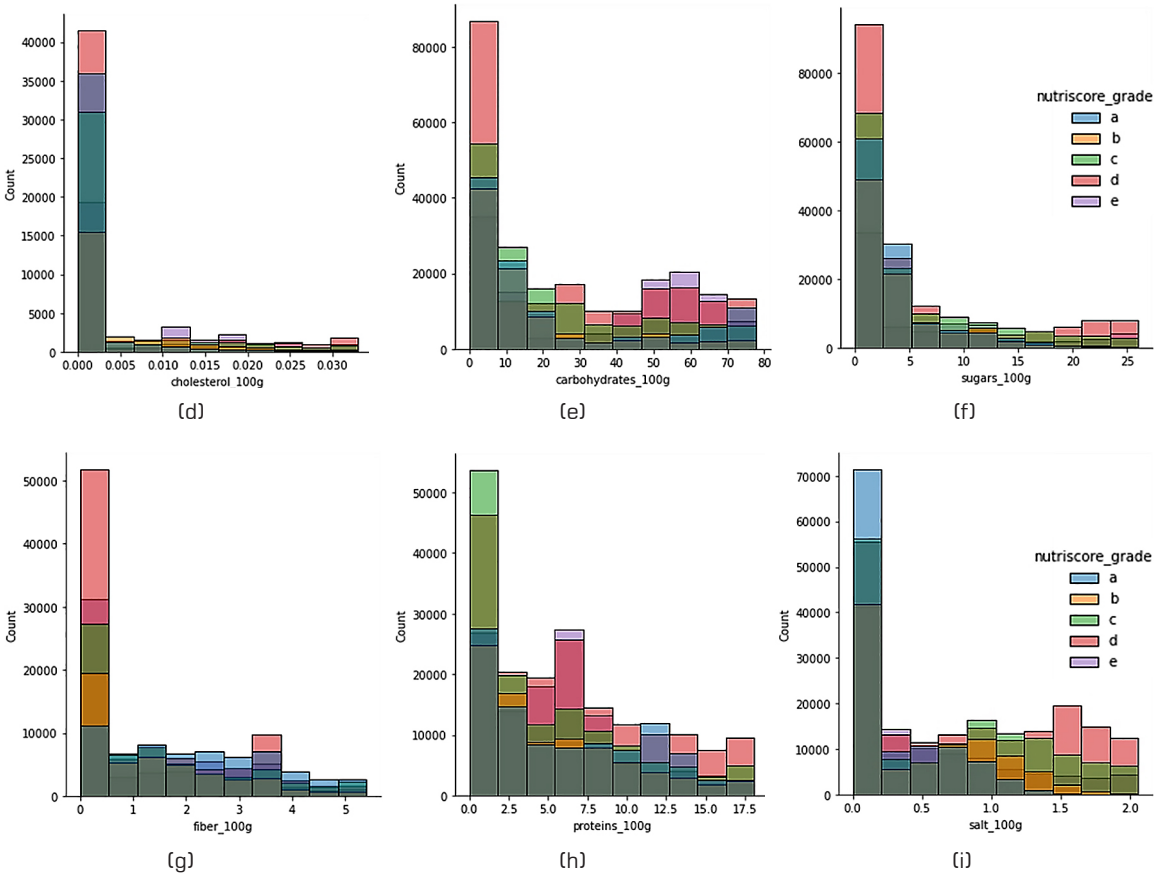


Figure 5. Distribution of different nutrients in cheese products (a) energy content, (b) fat content, (c) saturated fat content, (d) cholesterol content, (e) carbohydrates content, (f) sugars content, (g) fiber content, (h) proteins content, (i) salt content per 100 g of cheese.

This study demonstrates the application of data mining techniques in examining the nutritional value of various cheese products using the python platform. From the available dataset, it can be seen that the information is missing from various qualitative features, which limits its reliability. The well-known fact is that these techniques provide more robust and reliable predictions with a large and complete datasets containing no missing values. Thus, this study can be extended for big data with a full set of information on each variable for improving the current status quo, robustness, and the degree of certainty in making reliable predictions.

It may be noticed that the information in the available datasets was missing from various qualitative features. Data mining techniques are robust for a large and complete dataset that contains no missing values. Thus, this study can be extended for more reliable results after obtaining complete information on each variable and more data.

4. CONCLUSION

The essential nutrients such as proteins, minerals, and vitamins in cheese are known to provide health benefits via the production of specific peptides and free amino acids. However, due to the presence of saturated fatty acid, cholesterol, sugar and salt content, it suffers from adverse nutritional benefits. Thus, it is necessary to differentiate between good and bad cheese depending on the different nutrients it contains. This study used Python software data mining techniques to map the crucial nutrition value of industrial cheese produced in France as a test-bed study. A large dataset of Industrial cheese made in France was accessed to study nutrient values such as energy, fat, carbohydrates, protein, fiber, salt and cholesterol content.It was observed that high-grade cheese (type a and type b) has higher fiber and protein content with lower salt, sugar, cholesterol, energy, carbohydrates, total fat, and saturated fat

per 100 g of cheese. Thus, this study suggests that one should consider minimizing consumption or switching of cheese if their favorite cheese contains sugar of more than 25 g, salt of more than 2 g, or energy above 500 kcal to remain healthier.

This study advocates using data mining techniques for illustrative visualization of complex nutritional information supplied with the food products that can help consumers have an informed idea of taking a nutritive diet using simple tools like python. This study is especially helpful to 'Turophiles' (cheese lovers) as it can aid in selecting the right type of cheese to maximize the nutritive benefits. Furthermore, this study can be extended to analyze other food products for food labelling to enhance consumers' awareness of a safer choice.

Data availability

The data accessed and used for analysis in this paper can be downloaded from the open database: https://static.openfoodfacts.org/data/en.openfoodfacts.org.products.csv

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