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Nutritional Data on Selected Food Products Consumed in Oman: An Update of the Food Composition Table and Use for Future Food Consumption Surveys

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Abstract: Food composition data in the EMR countries are often lacking, obsolete or unreliable. The study aims to provide reliable and up-to-date nutrient data of selected food products consumed in Oman in order to evaluate consistency of nutrition labelling and update the current used food composition database. Contents of total fat, fatty acids, carbohydrates, total nitrogen, sugars and sodium were chemically analyzed in 221 foods and beverages purchased in 2022 and label and corresponding laboratory values were compared using the tolerance levels of the European Union. Food items were classified according their nutritional composition, the extent of processing and coded according FoodEx2 system. Results indicate that the nutrient values stated on a label align with the values obtained in the laboratory with the exception of a 6.3% discrepancy in TFAs content, where the reported values are higher than the appropriate reference values. The category with the highest frequency (71.5%) consisted of ultra-processed foods. In terms of inconsistencies in the nutrition claims, 5.1% of food products with claims did not comply with the statement "sugar free" or "low salt". These findings underscore the significance of vigilant monitoring of nutritional labels as a means to implement measures that promote the well-being of consumers.

Keywords: laboratory values; nutrition label; ultra-processed products; NOVA system; nutrient profile; FoodEx2 system; traffic light label

1. Introduction

Food composition tables (FCTs) are used for various sectors including research, education, health, trade, agriculture, industry, food processing, retailing, and are therefore useful in manifold ways, such as nutritional surveillance, food consumption survey, nutrition labeling, siding diet and disease evaluation challenges, developing school menus or standards meal planning, setting dietary guidelines and even assessment of environmental impact of foods [1–7].

FCTs provide information relating to nutrient composition of foods with specific reference to energy, major components (water, protein, fat, carbohydrate, alcohol, ash), inorganic constituents, vitamins and other components (flavonoids, phytoestrogens phytonutrients, additives, pesticides and other residues). The nutrient values are either based on chemical analyses performed in analytical laboratories or calculated from the nutrient contents of recipe ingredients using retention

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and/or yield factors [8]. They are also borrowed values from other tables and databases or presumed values [8].

The Eastern Mediterranean Region (EMR) is facing the challenges to reduce the growing burden of diet-related non communicable diseases (NCDs) including type 2 diabetes mellitus, cardiovascular diseases (CVDs), chronic respiratory disease and some types of cancer [9]. Unhealthy diet is the major risk factor for raised blood pressure, overweight and obesity, raised blood glucose and raised lipids, which are metabolic and physiological risk factors of NCDs. Increased salt consumption is associated with hypertension and CVDs and there is evidence that lower sodium consumption can have a beneficial effect on these morbidities [10–14]. Saturated fatty acids (SFAs) are associated with increased serum levels of low-density lipoprotein, CVDs and incidence of cancer [15,16]. Trans fatty acids (TFAs), are recognized as harmful nutrients, associated with an increased risk of CVDs and mortality [17,18].

In the vast majority countries of the EMR, average intakes of salt are almost double WHO recommended levels (i.e. less than 5 g per day), sugar intakes are also well above WHO recommendations (free sugars less than 10% of total energy intake), intakes of total fat (TF) have steadily increased over the last 50 years, TFAs intakes are over 1% and SFAs intakes are above the recommended upper limit (10% of total daily energy) [19,20].

Reducing sugar, fat, and salt consumption, in line with WHO's best buy recommendations, is a feasible and meaningful health solution to prevent and control NCDs. The implementation of WHO recommendation to reduce salt, sugar, TF, TFAs and SFA consumption has led to a greater focus on reliable nutrient data, hence the need for databases to be reviewed regularly. Data on the composition of foods in the EMR countries are often lacking, obsolete or unreliable. Some countries do not have food composition data. In this context, the main objective of our study was to provide reliable data using laboratory analysis on nutritional composition of selected food products consumed in the Sultanate of Oman, an EMR country, in order to use them to: i) compare label and laboratory values in the selected food products; ii) update the current used FCT; iii) assess food consumption patterns of the population.

2. Materials and Methods

The design, sampling and laboratory analyses were done in 2022.

2.1. Study Area

Sultanate of Oman, an EMR country with a land area of 309,500 km² and a population of 5.032 million in 2023, has recently undergone rapid increase of NCDs burden with significant social and economic impact in terms of health care, loss of productivity and premature mortality [21]. Recent study reported that two-thirds of Omani adults were overweight or obese, one-third obese, one-third have high blood pressure or was currently under medication and more than 15% having a diagnosis of raised blood glucose or were on diabetes meds and/or diagnosed with diabetes [22]. Unhealthy diet behaviours of Omani adults underlined the predominance of NCDs burden in the country, e.g., 61% did not meet the recommended number of five servings/day of fruits and/or vegetables; 76% added often/always salt to food before or when eating; 25% reported eating processed food high in salt; 80% consumed vegetable oils. The most prevalent risk factor is primarily related to high salt, sugar and fat intake [22] that is why our study focused on the assessment of the level of these nutrient in the food products frequently consumed by Omani population.

2.2. Identification of food products

In order to obtain a list of the most consumed food products, four of the big hypermarkets from the Governorate of Muscat (Oman capital city) was contacted. Muscat governorates markets were chosen due to the presence of many citizens from different governorates of the Sultanate and the compilation of the most common options in foodstuffs. One of those hypermarkets respond to us and send us the list of all foods and drinks sold in the market as this type of information is confidential for most the markets. The list was sorted and the most consumed products were selected. In each food item from the top five, we choose the Omani brands to facilitate the reformulation's interventions in addition to the other brands in the top five list. A final list of 221 food items was selected from the most consumed products and purchased from the markets.

2.3. Analytical parameters

Chemical analyses to assess the nutrient contents of the selected food products were carried out in the United Integrated Laboratories located in Barka near the capital Muscat. For every food item, the content of total fat (g), SFAs (g), polyunsaturated fatty acids (PUFAs) (g), monounsaturated fatty acids (MUFAs) (g), TFAs (g), carbohydrates (g), total nitrogen (g), total sugars (g), glucose (g), sucrose (g), maltose (g), lactose (g), sodium (g) were analyzed. Official methods of analysis of Association of Official Analytical Chemist (AOAC) were used to analyze nutrients in foods [23–27] (Table 1).

Table 1. Analytical methods of nutrient in food products.

Test Parameters	UIL Method of Test	Reference Method
Total Fat (TF)	UIL-SOP-TECH-033	AOCS Official Method Ce 2-66, 2017 [23].
Saturated Fatty Acids (SFAs)	UIL-SOP-TECH-033	
Poly Unsaturated Fatty Acids (PUFAs)	UIL-SOP-TECH-033	
Monounsaturated Fatty Acids (MUFAs)	UIL-SOP-TECH-033	
Trans Fatty Acids (TFAs)	UIL-SOP-TECH-033	
Sodium (Na)[1]	UIL-SOP-TECH-008	Official methods of analysis of AOAC international, 2008 [24].
Total Sugar	UIL-SOP-TECH-023	Official methods of analysis of AOAC international, 2007 [25].
Glucose	UIL-SOP-TECH-023	
Fructose	UIL-SOP-TECH-023	
Sucrose	UIL-SOP-TECH-023	
Maltose	UIL-SOP-TECH-023	
Total Nitrogen[2]	UIL-SOP-TECH-014	Official methods of analysis of AOAC international, 2008 [26].
Carbohydrates	UIL-SOP-TECH-016	Official methods of analysis of AOAC international, 2002 [27].

[1]. Salt values are calculated from total sodium (Na) value multiplied by sodium conversion factor: *Salt = Na*2.5* [8]. [2]. Total protein values are derived from the total nitrogen (N) value multiplied by the nitrogen conversion factor: *Total protein = N*6.25* [8].

The energy content of each food item "as sold" was calculated according to the following formula [8,12]:

Energy kcal (kJ) = [carbohydrates*4 kcal/g (17 kJ/g) + total fat*9 kcal/g (37 kJ/g) + protein*4 kcal/g (17 kJ/g) + fiber*2 kcal/g (4 kJ/g)

2.4. Food products description

2.4.1. Food items coded according FoodEx2 system

In order to harmonize our food dataset and allow comparison across groups and countries, we used FoodEx2, a standardized system of Global Dietary Database and WHO/FAO GIFT for classifying and describing food data [28–30]. FoodEx2 consists of a core list of food items that represent the minimum level of detail needed for food assessments, and facets that provide further detail to the information of the food list term. The nature of the food itself is linked to level of processing: raw primary commodities (RPC), RPC derivatives, composite foods. RPC are unprocessed single-component foods or whose nature has not been changed by processing. RPC derivatives are single-component foods which have been physically changed by processing. Composites are foods consisting of multiple components [31].

2.4.2. Food items classified according NOVA system

The NOVA Classification, which was developed in 2010 by Monteiro (Brazil) and is popularized around the world, does not take account of nutritional values but rather the extent of processing of the foods. It distinguishes four food groups according to the extent of their processing [32].

- NOVA 1- Unprocessed or minimally processed foods: are natural foods subjected to one or more essentially physical processing operations that do not substantially alter the nutritional properties or manner of consumption of the original foods
- NOVA 2- Processed culinary ingredients: are substances derived from the group 1 foods by physical and chemical processes such as pressing, refining, grinding, milling and spray-drying (oil, butter, sugar), or derived directly from nature, such as salt. They are used for preparing, seasoning and cooking Group 1 foods.
- NOVA 3- Processed foods: are products designed to increase the durability of group 1 foods by modifying or enhancing their sensory qualities. This can be made essentially by adding salt, sugar, oil, vinegar or other culinary substances from group 2 to group 1 foods (canned fish, fruits or vegetables, fruit preserves, cheeses, fresh bread products).
- NOVA 4- Ultra-processed foods (UPFs): are industrial formulations typically made from five or more ingredients, or even more. These ingredients are often those used in processed foods, such as sugar, salt, oils or other fats, stabilizers and preservatives. The processes used for combining the usually numerous ingredients and for creating the "ultra-processed" end product include several processes without any domestic equivalents, such as hydrogenation and hydrolysis, extrusion and molding, and pre-treatment for frying.

Our food items were classified into the 4 NOVA groups.

2.4.3. Food items classified according the EMR nutrient profile

Data provided from chemical laboratory analyses were used to classify food products according the nutrient profile model developed by the WHO for the EMR [33]. It consists of classifying foods according to their nutritional composition in order to allow differentiation between foods that can form part of a healthy diet and those that are less healthy.

The model consists of 18 food categories or groups for which thresholds have been established in relation to the energy, total fats, saturated fats, total sugars, added sugars, non-sugar sweeteners and salt. The thresholds not to be exceeded are based on the dietary objectives recommended by the WHO for the prevention of obesity and related non-communicable diseases, as well as on the recommendations concerning sugars and salt [34–36]. If one of the thresholds is exceeded, no marketing action aimed at children should be permitted. This model was used to classify our food items in three groups according the permission or not of their advertisement: "permitted", "permitted subject to certain conditions" and "not permitted".

2.5. Different uses of food composition data

In addition of the food consumption surveys, the food composition data have a wide variety of uses including nutrition labelling, complying with national and international standards and regulations, as well the promoting healthy diet.

2.5.1. Creation of Front of Pack (FoP) nutrition labelling

The FoP colour-coded nutrient-based schemes were developed in accordance with the guidance of UK Food Standards Agency [37] and contains:

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Format "energy + 4": information on the energy value in kcal and kJ, plus the amounts of total fat, saturates, sugars and salt in grams per 100 g/ml and per portion of the product "as sold".

Descriptors "High", "Medium" or "Low" together with the colours red, amber or green respectively to reinforce their meaning. Criteria from Regulation (EC) No 1924/2006 [38,39] for red (HIGH), amber (MEDIUM) and green (LOW) were used (Table 2).

Table 2. Criteria for 100 g/ml of foods and drinks (per 100 ml) [32].

	Food whether or not it is sold by volume				Drinks			
Text	**LOW**	**MEDIUM**	**HIGH**		**LOW**	**MEDIUM**	**HIGH**	
Colour code	**Green**	**Amber**	**Red** >25% of RIs	**Red** >30% of RIs	**Green**	**Amber**	**Red** >25% of RIs	**Red** >30% of RIs
Total Fat	≤3.0 g/100g	>3.0 to ≤17.5 g/100g	>17.5 g/100g	>21 g/portion	≤1.5 g/100ml	>1.5 to ≤8.75 g/100ml	>8.75 g/100ml	>10.5 g/portion
SFAs	≤1.5 g/100g	>1.5 to ≤5.0 g/100g	>5.0 g/100g	>6.0 g/portion	≤0.75 g/100ml	>0.75 to ≤2.5 g/100ml	>2.5 g/100ml	>3.0 g/portion
Sugars	≤5.0 g/100g	>5.0 to ≤22.5 g/100g	>22.5 g/100g	>27 g/portion	≤2.5 g/100ml	>2.5 to ≤11.25 g/100ml	>11.25 g/100ml	>13.5 g/portion
Salt	≤0.3 g/100g	>0.3 to ≤1.5 g/100g	>1.5 g/100g	>1.8 g/portion	≤0.3 g/100ml	>0.3 to ≤0.75 g/100ml	>0.75 g/100ml	>0.9 g/portion

2.5.2. Calculation of percentage reference intake

Percentage reference intake (% RI) given on a per 100 g/ml of the product "as sold" using 'Reference intake of an average adult (8400 kJ/2000 kcal) (Table 3). The daily reference intake (RI) for FoP nutrition labels set by the European Commission and Member States [37].

Table 3. Reference intake (RI) for FoP nutrition labels [37].

Nutrient	Value	Nutrient	Value
Energy (kJ)	8400	Carbohydrates (g)	260
Energy (kcal)	2000	Sugars (g)	90
Total Fat (g)	70	Protein (g)	50
Saturated fatty acids (g)	20	Salt (g)	6

The calculation of the % RI used the following formula: % RI = (Amount of per 100 g/ml)/RI x100.

The food item is considered a high source of the considered nutrient if % RI is > 20%, good source when % RI is between 11 and 20%, medium if % RI is between 5 and 10% and low if % RI is < 5%.

2.5.3. Comparison of Label and Laboratory nutrient values

Available food labelling values on protein, carbohydrates, total fat, SFAs, sugar, sodium were compared to the corresponding values obtained by laboratory analyses. The nutrition labelling compliance was tested using the tolerance thresholds set by the Regulation (EU) No 1169/2011 of the European Parliament including the uncertainty of measurement associated with a measured value

[40] and the Regulation (EU) 2019/649 of 24 April 2019 established for TFAs, other than TFAs naturally occurring in fat of animal origin [41] (Table 4). For every food item, food labelling value is considered compliant with the analyzed value if this later value is within the lower and the higher tolerance of the declared value, calculated using the following tolerance thresholds.

Table 4. Tolerances for food products other than food supplements [40,41].

Nutrient	Tolerances for food products	
Protein, carbohydrates, sugars	<10 g/100 g:	± 2 g
	10-40 g/100g:	± 20%
	>40 g/100 g:	± 8 g
Total Fat	<10 g/100 g:	± 1.5 g
	10-40 g/100g:	± 20%
	>40 g/100 g:	± 8 g
Saturated fatty acids	<4 g/100g:	± 0.8 g
	≥4 g/100 g:	± 20%
Sodium	<0.5 g/100g:	± 0.15 g
	≥0.5 g/100 g:	± 20%
Trans Fatty Acids	Not exceed 2 g per 100 grams of fat	

Among the analyzed food products, 32.6% (n=74) presented nutritional information with claims. Only compliance of claims on energy, protein, sugar and salt were tested using content thresholds set by the Regulation (EC) No. 1924/2006 for nutritional or health claims [42] (Table 5). For food products (with added vitamins and minerals claims), no laboratory data were available in order to compare or control the label values.

Table 5. Tolerances for food products with nutrition claims [42].

Nutrient	**Conditions applying to nutrition claims**
Low energy	The product does not contain more than 40 kcal (170 kJ)/100 g for solids or more than 20 kcal (80 kJ)/100 ml for liquids.
Sugar free	The product contains no more than 0.5 g of sugar per 100 g or 100 ml
Source of protein	At least 12 % of the energy value of the food is provided by protein
High protein	At least 20 % of the energy value of the food is provided by protein
Low salt	the product contains no more than 0,12 g of sodium, or the equivalent value for salt, per 100 g or per 100 ml

2.6. Statistical analyses of data

Management, check, calculation of the derived variables (energy) and creation of new classifications of the data files were performed using the Stata software (version 14.0; StataCorp, College Station, USA) [43].

3. Results

3.1. Food products description

Food products were categorized into eight aggregated groups from the nutrient profile food groups. Out of the total of 221 food products, 25.3% were sweet snacks, cakes, biscuits, chocolate and sugar confectionary, 20.4% dairy products, 19.5% beverages, 12.2% processed fruit, vegetables and legumes, 10.0% sauces and dressings, 8.6% processed meat, poultry and fish, 3.2% bread and cereal products, 0.9% natural food (Table 6).

Table 6. Proportion of nutrition components found on the product label by category of food.

Food groups	Total products		Label clear to read	Food packaging claim	Mandatory nutritional information[1]
	n	%			
Group1: Natural food	2	0.9	100.0	0.0	0.0
Group2: cakes, biscuits, chocolate, sugar confectionary	56	25.3	46.4	37.5	76.4
Group3: Bread and cereal products	7	3.2	14.3	100.0	85.7
Group4: Dairy products	45	20.4	86.7	53.3	71.1
Group5: Processed meat, poultry and fish	19	8.6	52.6	63.2	57.9
Group6: Processed fruit, vegetables and legumes	27	12.2	70.4	18.5	25.9
Group7: Sauces and dressing	22	10.0	63.6	22.7	54.6
Group8: Beverages	43	19.5	83.7	44.2	27.9
Total	221	100.0	66.5	42.1	55.5

1: energy, fat, saturates, carbohydrate, sugars, protein and salt.

Our analysis found that only 66.5% of these products displayed clear food information to consumers and 55.5% mandatory nutritional information (energy in both kilojoules (kJ) and kilocalories (kcal), fat, saturates, carbohydrate, sugars, protein and salt) [39]. Among these food products, 42.1% had claims on the package (Table 6).

According the FoodEx2 system classification, 52.0% of the food item products analyzed by our laboratory were composites, 46.6% were raw primary commodity derivatives and only 1.4% were raw primary commodities (Supplementary Table 1).

The distribution of food products classed according to the NOVA system is detailed in the Supplementary Table 2. According to the extent of industrial processing, ultra-processed and processed food products were the most frequent with an overall average frequency of 88.2% (71.5% and 16.7%, respectively) (Figure 1). Details on NOVA classification are reported in the Supplementary Table 2.

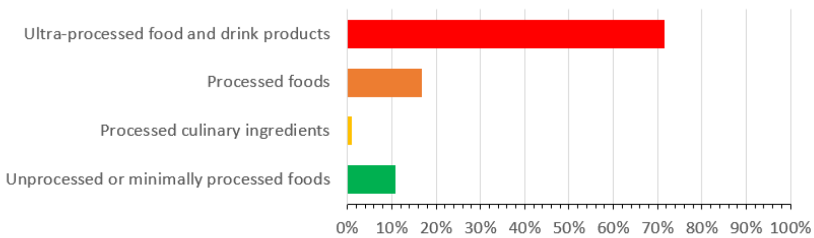

Figure 1. Frequency (%) of food products classed according to the NOVA system.

Overall the 221 analyzed food products, only 12.2% were exempt from marketing restrictions and considered to be part of a healthful diet according the nutrient profile model used in EMR region. For the other items of products, 35.3% were classified as "not permitted marketing" category (the whole category is classified as not permitted and don't need to check the levels for salt, sugar, SFAs, total fat). Out of the remaining 52.5% products, 19.0% as not permitted because of high salt; 10.4% not permitted because of high salt and total fat; 9.5% not permitted for excess of sugar; 5.0% not permitted because of high total fat; 5.0% not permitted for excess of salt, total fat and SFAs; 1.8% not permitted for excess of salt and sugar; 0.9% not permitted for excess of total fat and sugar; 0.5% not

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permitted for excess of total fat and TFAs; 0.4% not permitted for excess of SFAs and salt. Results are detailed in the Supplementary Table 3.

3.2. Energy and nutrient composition of food products

Energy and nutrient contents of each food item product assessed by laboratory analyses were detailed in the Supplementary Table 4. Table 7 presents energy, macronutrient and sodium values in food products classified into eight groups.

Table 7. Energy and nutrient values for 100 g edible portion of food products distributed into categories.

	Natural food (n=2)	Sweet snacks, cakes, biscuits, chocolate and sugar confectionary (n=56)	Bread and cereal products (n=7)	Dairy products (n=45)	Processed meat, poultry and fish (n=19)	Processed fruit, vegetables and legumes (n=27)	Sauces and dressing (n=22)	Beverages (n=43)
Energy (kJ)	1407.4[1]	1933.9	1744.8	745.8	761.0	488.2	592.4	461.4
	1393.0-1421.9[2]	486.2-2669.3	1624.5-1974.2	121.0-1468.5	450.5-1116.6	212.1-1667.9	11.6-2992.9	55.3-2201.8
Energy (kcal)	331.2	461.6	412.7	179.8	181.8	115.4	142.3	109.2
	327.8-334.6	115.1-643.3	383.0-470.7	28.7-353.5	106.0-268.8	50.1-392.7	2.72-727.5	13.0-526.8
Protein (g)	0	7.3	10.3	6.8	18.3	4.3	0.8	2.1
	0	0.0-26.0	7.2-18.3	1.7-24.3	11.7-25.6	0.4-7.6	0.0-5.2	0.0-24.9
Total Fat (g)	0	22.2	7.2	14.8	9.4	1.7	9.7	2.2
	0	0.0-51.9	2.0-20.9	0.6-34.1	0.0-20.6	0.0-20.8	0.0-79.2	0.0-29.6
Saturated Fatty Acids (g)	0	9.5	3.3	9.7	4.0	0.4	2.2	1.4
	0	0.0-26.8	0.4-11.4	0.4-27.8	0.0-10.3	0.0-2.3	0.0-13.6	0.0-20.2
Poly Unsaturated Fatty Acids (g)	0	4.0	1.3	1.4	2.1	0	0	0
	0	0.0-18.6	0.5-2.7	0.0-7.3	0.0-5.9	0	0	0.0-0.7
Monounsaturated Fatty Acids (g)	0	8.8	2.6	3.3	3.4	0.7	2.4	0.5
	0	0.0-30.1	0.1-6.9	0.1-11.4	0.0-8.2	0.0-11.7	0.0-22.0	0.0-6.5
Trans Fatty Acids (g)	0	0.1	0	0.2	0	0	0	0
	0	0.0-4.1	0	0.0-1.8	0.0-0.2	0	0	0.0-0.7
Carbohydrates (g)	82.8	58.2	76.6	5.0	6.0	20.8	12.8	20.3
	81.9-83.6	13.7-125.3	62.1-84.2	0.0-15.4	1.0-20.9	9.4-88.3	0.4-41.6	3.0-96.9
Total Sugar (g)	80.7	20.4	18.9	2.7	0.5	6.3	9.5	18.7
	80.3-81	0.0-81.5	8.2-27.7	0.0-15.3	0.0-4.0	0.1-63.8	0.0-34.1	2.2-96.9
Glucose (g)	37.1	3.9	3.1	0.4	0.4	3.0	3.6	3.0
	37.1-37.2	0.0-81.5	0.2-9.8	0.0-1.8	0.0-3.4	0.0-33.	0.0-17.8	0.0-31.9

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Fructose (g)	43.4	1.0	2.4	0	0.1	1.2	2.7	3.0
	42.9-43.8	0.0-6.8	0.0-9.9	0.0-0.2	0.0-0.2	0.1-15.9	0.0-15.6	0.0-28.7
Sucrose (g)	0.1	15.1	13.7	0.5	0.1	1.7	3.1	9.5
	0.1-0.1	0-52.5	4.0-28.1	0.0-11.4	0.0-0.6	0.1-8.1	0.0-16.3	0.0-87.9
Maltose (g)	0.1	0.6	0.2	0	0	0.4	0.8	0.2
	0.1-0.1	0-5.7	0.0-1.1	0.0-0.2	0.0-0.1	0.0-9.0	0.0-7.7	0.0-3.9
Lactose (g)	0.1	1.3	0.1	1.9	0.1	0.1	0.4	3.2
	0.1-0.1	0.0-8.1	0.0-0.3	0.0-6.2	0.0-0.8	0.0-0.5	0.0-2.0	0.0-45.9
Sodium (mg)	0	338.6	433.8	540.8	485.0	690.0	3372.7	44.4
	0	0.0-1542.5	0.3-1364.3	0.0-1898.8	211.2-1301.1	0.0-5040	163.5-19900	0.0-329.7

[1]: Mean. [2]: min-max.

On average, these food products contain protein between 0 (Group1) and 18.3 g (Group5), total fats between 0 (Group1) and 22.2 g (Group2) and carbohydrates between 5 (Group4) and 82.8 g (Group1). The highest average SFAs content was found in dairy products group (9.7 g) with a maxi content of 27.8 g. The highest TFAs content (4.1 g) was found in (Group2). The lowest and highest total sugar content were shown in Group 1 (80.7 g) and Group 5 (0.5 g). Sucrose content ranged between 0.1 g reported both in Group1 and Group5, and 15.1 g found in Group2. Maltose and lactose content did not vary much between the analyzed food items. Sauces and dressing were the highest in sodium content.

3.3. Food products categorized according the front of pack nutrition labelling

The traffic-lights label system based on the levels of total fat, SFAs, sugars and salt content showed that only 2.7% of food products were considered as healthy as all stated nutrient levels were low. Out of the remaining items, 32.2% showed medium or high levels of one of the stated nutrients, 13.6 % contain medium or high level of two of stated nutrients, 33.0% contain medium or high level of three of stated nutrients, and 18.5% contain medium or high level of all stated nutrients. Details of results regarding the FoP categorization are reported in the Supplementary Table 5.

3.4. Daily reference intake scores provided by food products

For nutrients to be limited, high sources (equal or above 20% of daily reference intake) were found in 35.8% of total food products for total fat, 58.8% for SFAs, 21.3% for sugars and 28.5% for salt, while low sources were found in 52.9%, 43.4%, 47.1% and 35.3%, respectively (Table 8).

Table 8. Percentage of daily reference intake scores of analyzed food products.

Nutrient	**Percentage daily reference intake provided by food products**			
	Low score[1] (%)	**Medium score[2] (%)**	**Good score[3] (%)**	**High score[4] (%)**
Energy	39.8	15.4	22.6	22.2
Protein	33.9	23.5	25.3	17.2
Carbohydrates	47.1	21.3	8.1	23.5
Sugars	47.1	13.6	18.1	21.3
Total Fat	52.9	3.6	7.7	35.8
Saturated Fatty Acids	43.4	6.8	8.6	58.8
Salt (g)	35.3	14.0	22.2	28.5

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[1]: Percentage of daily reference intake is < 5%. [2]: Percentage of daily reference intake between 5 and 10%. [3]: Percentage of daily reference intake between 11 and 20%. [4]: Percentage of daily reference intake is > 20%.

For energy, 22.2% of food products were high sources and 39.8% low sources. Only 17.2% of food products were high sources of protein and 23.5% were for carbohydrates. More details regarding the percentage daily reference intake and scores were reported in the Supplementary Table 6.

3.5. Accurateness of the nutritional labels

In the context of food labelling, all reported nutrient values, specifically protein (95.5% of all food products), carbohydrates (96.0%), total fat (96.0%), saturated fatty acids (84.6%), sugars (86.0%), and sodium (90.0%), were found to be consistent with the analyzed samples in the laboratory. Concerning the laboratory values for TFAs, 6.3% of the total food products presented values exceeding the acceptable threshold of 2% of total fat, which falls within the range of 2.7 to 61.7 g/100 g of total fat. Details regarding results of lower and higher tolerance of every item were reported in the Supplementary Table 7.

3.6. Accurateness of the nutrition claims

Two types of food products with nutrition claims "sugar free" and "low salt" did not comply with the regulation while the other evaluated food items were compliant (Table 9).

Table 9. Percentage of daily reference intake scores of analyzed food products.

Name of Product & Brand	Claim	Nutrient content	Comment
Activia Full Fat Fresh Laban	Source of protein	*Protein*: 21.0% of energy value	Compliant
Activia Full Fat Plain Yoghurt	High protein	*Protein*: 24.8% of energy value	Compliant
Boildchick Peas Mara	Sugar free	*Sugar*: 0.74 g/100 g of the product	Non-compliant
Maggi Chicken Stock Less Salt	Low salt	Salt**:** 1.5 g /100 g of the product	Non-compliant
Lipton Peach Ice Tea	Low energy	Energy: 18.5 kcal /100 ml of the product	Compliant
Mazoon spread cheese cheddar	TFAs[1] free	TFAs: ≤ 0.5% of energy	Compliant
Mazoon spread cheese	TEAs free	TFAs: ≤ 0.5% of energy	Compliant

[1]: Trans Fatty Acids.

4. Discussion

This study provides the first comprehensive comparison of laboratory and label values for protein, carbohydrates, sugars, SFAs, TFAs and sodium in major agri-food products contributing in food consumption in Oman. The findings showed that, among the various food products analyzed in this research and categorized using the NOVA classification, the category with the highest frequency (71.5%) consisted of UPFs. This classification was corroborated by the FoodEx2 system, which identified nearly all UPFs (99.4%) as composite foods or RPC derivatives, indicating that these foods had undergone significant processing transformations. This result shows that FoodEx2 system catch perfectly the extend of food processing.

When examining the distribution of UPFs based on the number of red FoP traffic-lights, it was observed that 36.1% of items displayed one red traffic-light, while 40.5% had two, and 8.9% had three, and none receiving all four red traffic-light simultaneously (indicating high levels of fat, SFAs, sugars, and salt). Furthermore, UPFs were found to be prevalent within the green FoP traffic-light labelling category, with figures ranging from 39.9% in products low in fat to 38.6% in products low in saturated fatty acids (SFAs), through 39.9% in products containing sugar and 37.3% in products low in salt.

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Additionally, 14.6% of UPFs displayed no red FoP traffic-light labelling. These included items such as flavored milks, custards, industrial juices, and malt beverages.

It is well-established that UPFs tend to be high in energy, fats, sugar, and sodium, while lacking in dietary fiber and essential micronutrients [44]. Hence, it was expected that the frequency of UPFs would be reduced in the category signifying the highest nutritional quality, indicated either by the color green or the absence of red traffic-lights. Our results align with those of the UK National Diet and Nutrition Survey [45], which discovered that not all UPFs exhibited an unhealthy nutrient profile, with more than half of them lacking any red FoP traffic-lights. These findings imply that FoP traffic-light labelling, serving as a nutrient profiling system, is capable of distinguishing the nutritional quality of food and beverages to some extent, but it only partially captures the extent and purpose of food processing. In this research, we observed that two food items, both labeled with the same color on Front-of-Pack (FoP) traffic-light labels, actually belong to different NOVA classifications. As example, cream caramel received green and amber FoP traffic-light labels, but it falls under NOVA 4 (UPFs), whereas Laban up also received green and amber FoP traffic-light labels but is classified under NOVA 1.

Typically, products labeled with a green FoP traffic-light are perceived as healthier, which can lead to higher intentions to purchase. Hence, in the absence of information pertaining to other facets of food, consumers may primarily rely on the nutritional quality of food when making food choices, irrespective of other individual factors. In the other hand, food producers tend to reformulate their products to achieve more favorable FoP labelling by decreasing sugar, fat, and salt content or augmenting fiber content to attract consumers, regardless of the degree and scope of processing necessitated for such transformation.

UPFs are characterized as ready-to-eat products primarily comprised of limited or no whole foods, typically demonstrating low nutritional qualities [46,47]. This poses a substantial concern, particularly in light of the increasing worldwide consumption of UPFs. Previous research has shown an association between higher UPF consumption and adverse health outcomes such as obesity, hypertension, breast cancer, diminished life expectancy, and potential risk on both maternal and neonatal health [48–51]. Some studies have proposed that exposure to endocrine-disrupting chemicals may represent a potential mechanism linking UPF intake to adverse health outcomes [49,52,53]. In addition, an alternative meta-analysis, involving 40 prospective cohort studies, assessed the relation between UPFs and overall mortality. The findings showed a positive correlation between increased intake of sugar-sweetened beverages, artificially sweetened beverages, processed meat, and red meat, and all-cause mortality. Conversely, the consumption of breakfast cereals demonstrated an inverse association with all-cause mortality [54].

Nonetheless, in a recent investigation [55], the researchers examined the reliability and efficacy of the Nova classification system, aiming to ascertain whether this system yields consistent food categorizations among users and its capacity to inform public health policies or furnish valuable insights for consumers. Their findings suggested that the current NOVA criteria do not enable foods to be definitively categorized as ultra-processed, highlighting the need for enhancements in the NOVA classification system to improve the consistency of food assignments.

In the present study, when considering both ultra-processing and nutritional quality of foods, more than one-quarter of the analyzed food products were classified amber and red FoP traffic-light labelling. Processing and nutritional quality are two dimensions of food that may independently or together influence the risk of chronic diseases. Some studies have investigated their individual and combined contributions on overall dietary quality. In this sense, a cross-sectional observational study provides evidence that food nutritional quality and processing are not mutually exclusive, and should be considered as underpinning dimensions of the diet [56]. A prospective cohort study found that adults with poor diets and a higher intake of UPFs faced the greatest risk of all-cause and cardiovascular disease mortality [57]. A review of prospective cohort studies demonstrated that the association between UPFs consumption and obesity and health-related outcomes remained consistent, even after accounting for dietary quality or patterns [58].

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The findings of this study indicate that the nutrient values stated on a label generally align with the values obtained in the laboratory when using the tolerance levels of the European Union, with the exception of a 6.3% discrepancy in TFAs content, where the reported values are higher than the appropriate reference values. In terms of inconsistencies in the nutrition claims, 5.1% of food products with claims did not comply with the statement "sugar free" or "low salt". These findings underscore the significance of vigilant monitoring of nutritional labels as a means to implement measures that promote the well-being of consumers.

The limitation of this study lies in the potential bias introduced during the selection of food products, given that a majority of the chosen items were processed and UPFs accessible in the Oman market. All inquiries were thoroughly deliberated and resolved through unanimous consensus among all the authors.

5. Conclusions

The results showed consistency between NOVA classification and FoodEx2 system in terms of food processing but the labelling captures only the nutritional quality of food and beverage and not the extend of food processing whereas they are complementary. In addition, non-compliance with nutritional claims and nutrition information was identified. These findings emphasize the importance of implementing strategies to address the regulation of UPFs and improve labeling and information for consumers. Government strategies should set up on the one hand, guidelines and regulations to limit the production and marketing of UPFs, especially targeting their negative health effects, and on the other hand, clear and informative labelling which includes not only the nutritional content but also any potential health risks associated with UPFs.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org., Table 1: Food description and coding according FoodEx2 system; Table 2: Classification of food products according the NOVA system; Table 3: Classification of food items according the EMR nutrient profile; Table 4: Nutrient composition of sampled food products; Table 5: Creation of Front of Pack (FoP) nutrition labelling in units of mass and units per portion; Table 6: Percentage reference intake (% RI) and Scores of IR information; Table 7: Label and laboratory values comparison.

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