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A Step toward a Sustainable Diet by Reducing Carbon Footprint: A Case Study in Iran

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ABSTRACT

Introduction: Greenhouse gas (GHG) emissions have caused environmental effects. Food production is one of the sources of GHGs. This study aimed to suggest dietary scenarios for decreasing GHG emissions.

Materials and Methods: GHG emissions in the target population of Urmia city, Northwest Iran, were investigated using a modeling approach. Three dietary scenarios were modeled and analyzed to evaluate and compare GHG emissions. The objectives and decision variables of the three scenarios included minimizing the carbon footprint and intake of food items, respectively. In the first scenario, the amount of energy intake was equal to baseline energy intake. The second scenario maintained the same energy intake constraint as the first scenario and made further alterations by considering the number of serving sizes suggested by the food pyramid for each food group. The third scenario was mostly based on this model by accounting for dietary reference intake for macronutrients, micronutrients, and energy.

Results: There was about 72% and 55.67% reduction in carbon dioxide equivalent (CO_2 eq) production in the first and second scenarios rather than the baseline diet of 4072.10 g CO_2 eq, respectively. In the final scenario, the CO_2 eq emissions were less than half of the baseline diet.

Conclusion: The study showed that a healthy diet with a higher proportion of vegetables, fruit, legumes, nuts, and dairy, and a lower share of red and white meat, egg, grains, fat and oil, and sweets can reduce CO_2 eq emissions.

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Introduction

Climate change is a threat to food security. Climate variability and related challenges have led to global hunger by affecting agricultural production in recent years [1]. The global increase in greenhouse gas (GHG) emissions is a significant concern that needs to be addressed. Many countries have programmed to reduce their emissions [2]. On the other hand, food production is the most considerable artificial pressure on the planet that threatens the local ecosystems and Earth system stability [3]. The global food system is responsible for about 35% of the GHG emissions in the world [4]. In recent years, there has been a trend in consuming more processed foods, and producers compete to use land, water, and energy, negatively affecting environmental sustainability [5]. It is estimated that in 2005, total emissions from cattle

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production were about 4623 million tonnes CO_2 eq [6]. The current food system is responsible for food and nutrition insecurity and is one of the most significant contributors to damaging the planet in all production, storage, and processing steps to consumption [7]. Therefore, it is required to create a global change in the food system to obtain sustainable diets [1, 3].

Sustainable diets have low environmental impacts, contributing to food and nutrition security and healthy life for present and future generations. Determining a dietary scenario with low GHG emissions is a step toward a sustainable diet [8, 9]. The idea of sustainable diets combines the difficulties inherent in developing a food system capable of providing nutritious foods to a growing population while minimizing environmental damage and remaining within planetary limits. In the last decade, research on sustainable diets has significantly developed [10]. According to the EAT-Lancet report, by 2050, it is necessary and achievable to follow sustainable dietary patterns with adequate caloric intake, including a variety of plant-based foods, unsaturated rather than saturated fats, and low amounts of refined grains, added sugars, animal-based and highly processed foods [3].

To the best of the authors' knowledge, no study has been conducted in Iran to design sustainable and environmentally-friendly dietary scenarios through reducing carbon footprint and considering health benefits. Therefore, this study aimed to suggest dietary scenarios to decrease GHG emissions by considering nutritional recommendations and the food preferences of individuals.

Materials and Methods

Study design and sampling

This modeling study was performed as part of a larger project entitled 'Designing and testing a multilevel model to explain the effects of the neighborhood, household, and individual levels on anthropometric factors in men and women living in the city of Urmia' [11-13]. The sample size of the main study was 723 (427 women and 296 men), aged 20-64 years in two ethnic groups (445 (61·5%) Azeri Turks and 278 (38·5%) Kurds). The procedures for sample selection and data collection are presented elsewhere [11]. Samples selection was conducted using a combination of the cluster, random, and systematic sampling methods. The selection was made from all four geographical zones (north, south, east, and west) of Urmia. Health centers were clusters that were randomly selected according to population size at each geographical zone. Then households were selected. In each center, the first household of each cluster was selected from the routine data registry of the center. The interview was done with household members (one man and one woman) by trained local nutritionists who were fluent in Turkish and Kurdish. Using the cluster sampling method, an attempt was made to minimize sampling error in the sampling stage.

Data collection

Dietary data were collected by a 168-item semi-quantitative food frequency questionnaire. The questionnaire utilizes a Willett format and was modified based on Iranian food items and was used to collect information on food intake over the past year [14]. The questionnaire contained a list of food items commonly consumed by Iranian people, with standard consumables. The participants in the study were asked to report the consumption frequency of each food item over the year prior to the study on a daily, weekly, monthly, or annual basis. The validity and reliability of this questionnaire have been reported and approved for the Iranian population [15]. However, to apply it in Urmia city, which is ethnically diverse, the content validity of the questionnaire was evaluated by five local nutritionists in the nutrition department of Urmia University of Medical Sciences [13]. In addition, to minimize the response error, individuals who reported energy intake over ± 3 standard deviations (SD) from the mean energy intake were excluded from the study.

Statistical analysis

After data collection, the consumption frequency of each food item was converted to each individual's daily intake over the previous year, and portion sizes were converted to grams by using household consumption units [16]. Then the mean intake of different food items in the study population was used to continue the calculations. An adapted version of NUTRITIONIST 4 software that allows the user to do nutritional analysis on single food items, recipes, meals, and entire diets and contains Iranian food composition table (version 7.0; N-Squared Computing, Salem, OR, USA) was used in this study. This software determined the amount of nutrients and energy in the mean intake of different food items of individuals, based on the amount of nutrients and energy in each food item. Those who failed to complete a minimum of 50% of the questionnaire items or their energy intakes were classified as incorrect reports according to the Goldberg method and were excluded from study [17].

The ‘carbon footprint' method was adopted to calculate CO_2 eq emissions during food production. The carbon footprint is a measure that shows how many kilograms of carbon dioxide eq is produced per kilogram of food, directly and indirectly, caused by an activity or is accumulated over the life stages of that product [18]. Since there is no data in this regard in Iran, the CO_2 eq emissions of each food item were taken from “BCFN Double Pyramid Database”. Food Climate List was used from the Swedish University of Agricultural Sciences for some food items that were not available in the BCFN data, such as candy, ice cream, tea, ketchup, imported fruit, oil, jams, legumes, and nuts. These data report kilograms of carbon dioxide eq produced per kilogram of food. Then, using this data and based on the mean food intake calculated, a simple proportion was used to calculate CO_2 eq for each food item [19].

Linear programming (LP) technique in the MS Excel (version 2013) Solver add-on was employed to model optimal food pattern while considering carbon footprint [20]. LP for designing diets has been described in detail elsewhere [21]. In this study, the LP-designed models were low- CO_2 eq based diets. The main elements of LP models include the objective, decision variables, and constraints. The objective sets the optimal goal. In the present study, the goal was to minimize the carbon footprint. Changing variables are those decision variables that can be varied to reach the objective by considering constraints. The decision variables in this study were the amounts of food items. The constraints are those conditions that must be fulfilled to reach the objective goal. LP investigated three scenarios to identify a healthy plate with a low carbon footprint for the Urmia population. These three scenarios aimed to investigate the effect of a step-by-step move from a regular diet to a healthy diet on carbon footprint. The objectives and decision variables for all three scenarios were minimizing the carbon footprint and intake of food items, respectively. To consider the population's dietary habits, in all scenarios, the first and third quartiles of the baseline food intake were considered the minimum and maximum amount of each food item. “Baseline diet” refers to the average observed diet in the study population.

In some cases where the third quartile cut point was less than a serving size, the latter was the maximum. Additional constraints for each scenario were set as follows. In the first scenario, the amount of energy intake of the model was equal to the baseline energy intake, which is the mean energy intake in the population. In the second scenario, in addition to the energy constraint of the earlier scenario, the number of serving sizes suggested by the food pyramid for each food group was considered a constraint. The recommended amounts of cereals, vegetables, fruit, dairies, meat, legumes, and egg in food-based dietary guidelines for Iran are 6-11 (minimum-maximum), 3-5, 2-4, 2-3, and 2-3 servings, respectively [22]. In the third scenario, in addition to all the constraints that were considered in the second scenario, the recommended dietary allowance (RDA) for macronutrients, micronutrients, and energy were considered constraints. An RDA is the average daily dietary intake level that is enough to meet the nutritional needs of 97 to 98 percent of healthy people in the community [23]. Since the studied population included male and female adults, based on their share in the sample size, the weighted average of WHO and FAO recommended for macronutrients, micronutrients, and energy were used [24-26]. These three scenarios were compared with "baseline diet" based on the contribution of each food group on total energy for each scenario, macro and micronutrient composition, and the amount of carbon footprint.

Ethical Issue

All procedures were conducted according to the latest version of the Helsinki Declaration. The study was approved by the ethics committee of "Student Research Committee" "Research Technology Chancellor" in Shahid Beheshti University of Medical Sciences, Tehran, Iran (IR.SBMU.RETECH.REC.1396.495).

Results

Data were analyzed for 695 participants. Due to the misreporting of energy intake and incomplete food frequency questionnaire (more than 50 % of items blank), 28 (4.9%) individuals were excluded. The results were ordered by model-generated diets of different scenarios and checked against baseline intake or RDA. The share of total energy intake supplied by each food group in the baseline model, and three scenarios are presented in Figure 1.

Regarding diverse sub-groups of the "meat, poultry, fish, dry legumes, egg, and nuts" group, the contribution of each sub-group in the baseline intake and three scenarios are presented in Table 1. Macro and micronutrient content of baseline intake and each scenario were compared with RDA (Table 2).

In the baseline model, the "bread, cereal, rice, and pasta" group (i.e., 39%) had the highest proportion of average energy intake 2920 Kcal. The lowest contribution belonged to "fruit" and "vegetables" (i.e., 8% contribution of each group). The amounts of macronutrients, micronutrients, and energy in the baseline diet were higher than RDA. The CO_2 eq emission of baseline intake was 4072.10 g for the daily food of a person.

In the first scenario, the LP goal was to minimize the carbon footprint while taking the same amount of daily energy without considering nutritional requirements. In this model, the share of "meat, poultry, fish, dry legumes, egg, and nuts" and "vegetables" in supplying daily energy increased by 168% and 200%, respectively, compared to the data from the baseline diet. On the other hand, the contribution of "milk, yogurt, and cheese" (93%), "bread, cereal, rice, and pasta" (56%), "fruit" (25%), and "fat, oil, and sweets" (16%), decreased.

The total contribution of red meat, fish and poultry, legumes, and egg decreased 95%, 69%, 26%, and 70%, respectively, and the share of nuts has increased about 16 times, in the first scenario compared to the baseline intake. In terms of macro nutritional components, carbohydrate was 6% less than RDA. Also, sodium intake was 54% more than RDA, and vitamin A, calcium, riboflavin, vitamin B12, and vitamin K intakes were 80%, 32%, 9%, 68%, and 21% less than the recommended values for adults, respectively. By these modifications, CO_2 eq emission was 1128.40 g and decreased by about 72.29% compared to the baseline intake.

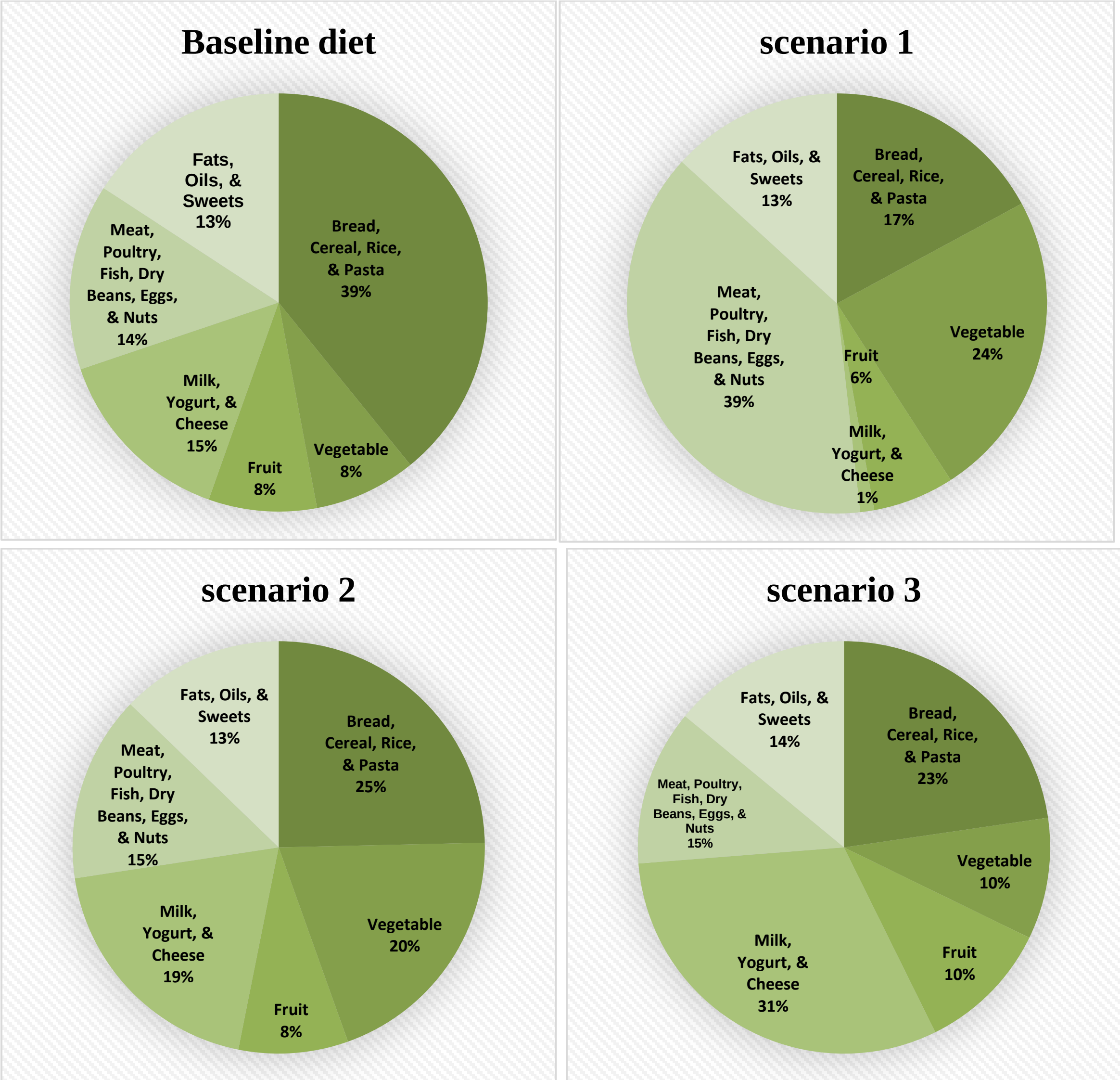

Figure 1: The portion of total energy intake supplied by each food pyramid group according to baseline diet and modeled scenarios

Table 1: The contribution of each food subgroup in grams according to baseline diet and modeled scenarios

Subgroups	Baseline diet	Scenario 1	Scenario 2	Scenario 3
Meat, poultry, fish, dry legume , egg, and nuts	202.54	229.72	106.54	104.8
Read meat	51.30	2.7	2.70	3.95
Fish and poultry	51.32	15.86	15.86	15.86
Legumes	52.29	38.73	44.15	56.08
Nuts	9.66	161.01	32.40	17.49
Egg	37.98	11.46	11.46	11.46
Bread, cereal, rice, and pasta	532.56	221.12	319.76	314.93
Vegetables	448.41	465.61	383.58	334.69
Fruit	449.03	184.79	299.84	294.76
Milk, yogurt, and cheese	452.29	39.64	547.42	433.95
Fat, oil, and sweets	100.39	65.89	63.89	63.89

All values are reported in grams.

Table 2: The amount of micronutrients, macronutrients, and energy content according to baseline diet and modeled scenarios compared to RDA

	Baseline diet	Scenario 1	Scenario 2	Scenario 3	RDA
Kcal	2920.17	2920.17	2920.17	2675.24	2675.24
Protein (g)	111.30	80.48	75.20	75.96	50.1
Carbohydrate (g)	426.11	344.08	380.51	367.84	367.84
Fat, total (g)	93.15	147.95	106.05	86.12	89.17
Sodium (mg)	3704.89	2309.32	2809.63	1500	1500
Vitamin A (RAE)(mg)	860.00	157.85	212.95	782	782
Vitamin C (mg)	187.30	84.15	86.45	88.12	81.15
Calcium (mg)	1450.84	681.29	1507.50	1017.07	1000
Ferrous (mg)	23.97	18.89	19.56	16.72	13.9
Thiamin (mg)	2.85	2.18	2.27	1.89	1.14
Riboflavin (mg)	2.88	1.08	2.67	1.99	1.18
Niacin (mg)	32.45	22.36	21.68	17.73	14.82
Vitamin B6 (mg)	2.36	2.66	1.70	2.28	1.3
Folate, total (mg)	701.04	621.72	596.40	420.24	400
Vitamin B12 (mg)	6.58	0.76	2.52	2.4	2.4
Vitamin k (mg)	250.36	80.94	82.21	102.3	102.3
Magnesium (mg)	476.23	550.26	394.75	388.27	346.9
Zinc (mg)	15.57	13.97	8.83	9.57	9.23
Fiber, total (g)	78.73	60.63	76.87	44.71	30.33
Cholesterol (mg)	366.41	89.79	128.03	249.68	300
Saturated fat (mg)	32.50	26.51	26.68	29.72	29.72

In the second scenario, a new constraint to the earlier model was added, which was to decrease the share of "bread, cereal, rice, and pasta" and "fat, oil, and sweets" by 37%, and 19%, respectively, compared to the baseline diet. Consequently, the contribution of “vegetables” (151%), “fruit” (3%), “milk, yogurt, and cheese” (35%), and “meat, poultry, fish, dry legumes, egg, and nuts” (2%) increased in providing the daily energy 2920 Kcal. However, there was a decrease in the contribution of red meat (95%), fish and poultry (69%), legumes and egg (16%), in this scenario, and the share of nuts increased to 235%, compared to the baseline intake. The amount of vitamin A (73%), vitamin K (20%), and Zn (4%) were less than the RDA, while sodium was (87%) higher than the recommended values. CO_2 eq emission was 1805.1 g to supply a one-person diet for a day by following this scenario, which was 56% less than the baseline intake. Therefore, considering the food pyramid guidelines, the amount of CO_2 eq emissions had a lower decline than the earlier scenario, where these references did not restrict the model.

In the third scenario, which was restricted to the food pyramid guidelines and RDA, the contribution of “bread, cereal, rice, and pasta”, “meat, poultry, fish, dry legumes, egg, and nuts”, and “fat, oil, and sweets” in providing average daily energy declined by 42%, 15%, and 12%, respectively, compared to the baseline diet. Also, the contribution of “vegetables” (20%), “fruit” (25%), and “milk, yogurt, and cheese” (115%) increased. The share of meat (92%), egg (70%), and also poultry and fish (69%), were less than the baseline intake. However, consumptions of legumes and nuts were, respectively, 7% and 81% more than the baseline intake. In this scenario, CO_2 eq emission was 1928.09 g, which was 52% less than baseline intake.

Discussion

The present study suggested three different dietary scenarios for the target population to reduce CO_2 production and provide a sustainable diet. The highest reduction in CO_2 production (72%) compared to the baseline model was observed in the first scenario, which had an energy content equal to the baseline model but a

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larger amount of nuts within the meat group, followed by the second scenario (55.67% reduction in CO_2 production). In the third scenario that was completely in accordance with the food pyramid and RDA, the CO_2 emission was less than half of the baseline model.

In the target population, per capita intake of rice and bread, oil, and sugar was 5%, 20%, and 38% more than the recommended values, respectively, while legumes, milk and dairy, egg and vegetables, and fruit consumption was lower than the recommended values. This type of food pattern is a challenge to food security in Iran [27]. The majority portion of individual intake in the target community in Urmia was from bread and cereal (39%) and then fat (16%), and the least was for fruit and vegetables (8%).

Reducing the amount of dietary animal-based products was identified as a way to reduce carbon footprint [28]. In the present study, the alternative scenarios with lower carbon footprints had a lower share of animal sources and a higher share of subgroups with plant sources. These alterations are consistent with previous research, indicating that meat production contributes 15%-24% of the total GHG emissions, primarily because of deforestation for grazing and having longer-lived animals required in meat production [29, 30]. Similarly, removing meat from the UK diet resulted in a 35% decrease in GHG emissions [31]. According to Springmann et al., substituting plant-based meals for animal-based foods is especially successful in high-income nations for mitigating certain environmental effects, most notably GHG emissions (reductions of up to 84%) [10]. Soret et al. showed that moderate variations in meat product caloric consumption resulted in significant reductions in GHG emissions and better health outcomes, as shown by mortality studies [32].

By decreasing the meat group in this study, the contribution of legumes and nuts within this group increased. The amount of GHG emissions of ruminant meat (beef and lamb) per gram of protein is about 250 times more than legumes [33]. Animal-based foods need more energy use than foods with a vegetable origin, so that they can affect the climate more seriously. The average fossil energy required for all animal protein production systems is more than 11 times that for grain protein production [34]. Therefore, substituting legumes for meat may represent a healthy sustainable diet, but monitoring essential nutrients like zinc and iron is essential [35, 36].

Along with the shift in the proportion of the subgroup of meat, poultry, fish, egg, legumes, and nuts, the increased share of vegetable consumption also decreased CO_2 emissions in contrast to baseline intake. Similarly, substituting fruit and vegetables for meat is illustrated to decrease diet-related GHG emissions in France [33]. With a few minor deviations from what we observed, Chen et al. showed that a sustainable diet would involve a significant decrease in meat and vegetable oils consumption, a moderate drop in cereals, roots, and fish products consumption, and an increase in legumes, nuts, seeds, fruit, and vegetables consumption [37].

The dietary scenarios in this study also showed a reduction in fat, oil, and sweats. Vegetable oils have a lower carbon footprint and should be replaced with butter and hard margarine, and shortenings. Sweets and cakes probably have a high carbon footprint, although there is a lack of data on their contribution [38].

The present study is one of the few that deals with the relationship between diet and GHG emissions in Iran. A valid food frequency questionnaire was used. The cluster sampling method was used to minimize sampling error. However, a series of limitations should be considered in evaluating results. Although it was tried to exclude participants who reported their energy consumption more or less, when using a food frequency questionnaire to assess dietary intake, problems, such as under-reporting baseline intake or invalid reporting due to social desirability bias might have occurred [39].

Additionally, sustainable diets have different determinants like economic, environmental, culture, and health [40]. This study considered only two dimensions, including the recommended diet (health aspect) and CO_2 emissions (environmental dimension). It would be better for future studies to consider other elements of a sustainable diet. In the present study, dietary habits of the population were considered in all scenarios as profiles of cultural and economic preferences of people. The suggested diet was limited to the first and third quartiles of the baseline food intake. However, suggested changes in the diet need to be more investigated from a feasibility aspect in future studies. Another problem was that there is not any carbon footprint data in Iran. Given that differences in the conditions of some countries, such as climatic conditions, can affect the carbon footprint of food items, the use of carbon footprint in other countries is not correct for Iran.

Conclusion

A healthy diet with a higher proportion of vegetables, fruit, legumes, nuts, and dairy group and lower consumption of meat, fish and poultry, egg, bread, cereal, rice, pasta, fat, oil, and sweets can supply all recommended dietary allowances while reducing CO_2 eq emissions. However, the possibility and acceptability of varying amounts of the mentioned dietary groups must be established in a variety of geographical and sociocultural situations.

Abbreviations

FFQ: Food Frequency Questionnaire
RDA: Recommended Dietary Allowance
WHO: World Health Organization
LP: Linear Programming
FAO: Food and Agriculture Organization

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Conflict of interest

The authors declare that there is no conflict of interest.

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Appendix 1: the weight of one serving and recommended serving size of different food pyramid groups [22].

Food groups	Recommended serving size	The weight of one serving
Bread, Cereal, Rice, & Pasta	6-11	26 g for bread, 75 g for others
Meat, Poultry, Fish, Legumes, Egg, & Nuts	2-3	66 g for meat & poultry, 75 g for fish, 120 g for egg, 114 g for legumes & nuts
Vegetables	3-5	85 g
Fruit	2-4	120 g
Milk, Yogurt, & Cheese	2-3	240 g for milk &yogurt, 52 g for cheese
Fat, Oil, & Sweets	Minimum	-

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