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Barriers and facilitators of nutrient intake efficiency in Iran

(a new perspective on food waste management)

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Abstract

Background

Paying particular attention to sustainable food consumption in low-income households is essential for reducing food waste. Due to the growing population globally, this concept will likely become more serious soon.

Methods

Following the importance of optimizing food consumption for sustainability, in this study, a novel methodology is introduced for calculating nutrient intake efficiency and determining the kind of choosing food to minimize food waste in different locations. Also, the impact of socio-economic factors on nutrition efficiency was assessed. Data Envelopment Analysis (DEA) and a Tobit model are used to achieve the goals. Household Consumption and Expenditure Surveys (HCES) of 30,000 rural and urban Iranian households were used in all provinces in 2016. Finally, the Nutrient Efficiency Map (NEM) of Iran was depicted by GIS software.

Results

The results showed that many townships had nutrient efficiency scores of less than 70%. Northeast townships had the lowest scores, with an efficiency score of less than 50%. Overall, townships have lower efficiency in the North (seaside cities), East (desert cities), and North East (isolated cities) compared with other areas.

Conclusions

Therefore, it is suggestible that the government should modify the support policies and the protection packages based on social, geographical , and cultural status.

Keywords: Data envelopment analysis; Food waste; Nutrient intake efficiency; Optimization; Socio-Economics; Urban-rural areas

1. Introduction

Food waste, nowadays, is a global concern that threatens sustainable food systems and imposes considerable environmental costs and human externalities arising from the multiple processes involved in the human life cycle. More than one-third of food consumption for human in the world is lost or wasted [1]. Therefore, paying particular attention to sustainable food consumption in low income households is essential for reducing food waste [2]. This can be achieved optimally through choosing the best combination of food groups [3]. In fact, the best waste management via sustainable consumption of foods prevents or mitigates loss of resources and thus translates into considerable improvement in food security [1].

Using FCO (Food Consumption Optimization) that is choosing the best combination of food ingredients, can lead to a decrease household expenditure while nutrition is optimized. Households become more efficient in allocating limited food expenditures, leading to increase nutrient efficiency and decrease food waste. The FCO reduces the food waste due to the nutritionally inefficient consumption that is at least partly caused by inaccurate or insufficient knowledge.

Nutritional knowledge can be a critical policy component to combat malnutrition, to reduce food waste and to improve diet. Knowledge gaps exist in different regions and for different commodities, and these discrepancies may lead to a qualitative change in households' diet from healthy to unhealthy status. Reducing the amount of food waste has two substantial benefits in improving the quality of life: first, it allows households to avoid unhealthy diets; and thus second, it reduces adjustable risk for non-communicable diseases related mortality worldwide [4]. As Khan [5] shows, adopting the mortality-related axiom of biological stress in poverty measurement leads to a more accurate measure of poverty headcount ration. The first benefit of reduction in food waste therefore implies as a corollary, a possible reduction in a more accurately estimated poverty headcount ratio. The second benefit of avoiding less nutritious food is that results in monetary saving as well. Methods of food group selection, preparation and combination affect human health, food waste and reduce the prevalence of such diseases as diabetes, heart attacks, and strokes, among other non-communicable diseases [6]. As a methodology we will use a two stage DEA and Tobit regression. DEA is one of the well-known LP applications that is initially proposed by Charnes, Cooper & Rhodes in 1978 is a method for measuring the relative performance of homogenous DMUs with multiple inputs and multiple outputs [7]. Also, Tobit model is a technique for determining associated factors with calculated efficiency. This model which has been first reported by Tobin in 1958 has been widely used to determine effective factors on the efficiency [8]. Tobit regression is being frequently used by economists to analyze discontinuous dependent variables, and to analyze dependent variables subject to a known upper or lower bound [9].

Table 1 shows some studies that determined the amount of food waste and its social and environmental costs.

Table 1. The application of DEA approach in Health-Agricultural-Public systems.

Surveyed research	Studied area	Sector	Optimization by DEA	Resource management	Effective factors
Jia and Yuan [10]	China	Health system	Yes	Yes	No
Rosić et al. [11]	Serbia	Public	Yes	No	No
Zhou et al. [12]	China (Jiangsu)	Health system	Yes	No	No
Sun and Luo [13]	China	Health system	Yes	No	No
Li et al. [14]	China	Agriculture	Yes	No	Yes
Nabavi-Pelesaraei et al. [15]	Iran	Agriculture	Yes	Yes	No
Li et al. [16]	China	Agriculture	Yes	No	No
Li et al. [17]	China	Environment	Yes	No	No
Li et al. [18]	China	Agriculture	Yes	No	No
Rego et al. [19]	Brazil	Agriculture	Yes	Yes	No
Grados and Schrevers [20]	Peru	Agriculture	Yes	No	No
Nabavi-Pelesaraei et al. [21]	Iran	Agriculture	Yes	Yes	No
Zhang and Zhou [22]	China	Industry	Yes	No	No

Considering the urgent need to reduce food waste, this paper aims to:

- ✓ Develop a novel DEA & regression model to measure food consumption efficiency
- ✓ Determining the best combination of food groups for nutrient security using current food resources consumed by Iranian households.
- ✓ Identifying factors associated with nutrient efficiency by Tobit model.
- ✓ Proposing a method for depicting the geographical plot of nutrient efficiency for both rural.

2. Materials and methods

2.1. Sample description

Data and information are gathered from the Statistical Centre of Iran (SCI), which is responsible for the collection Iranian household expenditures and income annually through a questionnaire with proven reliability and validity. The SCI survey includes the consumption of 167 food ingredients within a household, the respondent is either the breadwinner or a member aware of the consumption of all household members, able to answer to all questions on behalf of the breadwinner [3].

We used the household data to measure nutrient intake. Inputs and outputs for each province were calculated by averaging household data in each province. Information of about 30,000 rural and urban households was gathered in 2016. All 167 food ingredients were divided into 14 food groups to calculate nutrient content consumed by household [23] in 316 townships. The coefficients of the nutrient content of food ingredients extracted from the NNFTRI (National Nutrition and Food Technology Research Institute) was used.

2.2. Nutrient intake

Nutrient intake, including calories, protein, calcium, iron, vitamin A and vitamin C, was used to identify households' nutrient status. Assuming a linear function, adult nutrient intake can be calculated by Eq. (1) [3]:

$$y_i = \sum_{j=1}^{n=k} \beta_j Z_{ij} + \varepsilon_i \quad (1)$$

Where y_i is the level of nutrient intake of each household member in a day; Z_{ij} is the amount of i -th food group consumed by the j -th person in a day and B_j is the nutrient contents of j -th foodstuffs. By dividing this matrix into the average number of household members [24] in each province, the matrix of nutrient intake for a person per year was calculated. Optimization consumption of food groups was calculated by DEA that shows in the Fig. 1.

Fig. 1. The conceptual framework of the extraction of nutrient intake efficiency for Iranian households.

2.3. Data Envelopment Analysis (DEA)

There are two main DEA models, refer to constant and variable returns to scale (CRS and VRS). We will be using a CRS model, since increasing consumption will increase output (here is nutrient intake) with the same ratio [25]. In respect to orientation, the aim of this assessment is on reducing unnecessary food consumption, and hence input orientation was assumed to minimize the food consumption and identify level of food waste. Consider a set of n DMUs, where DMU $_j$ has a consumption plan (X_j, Y_j) with $X_j = (x_{1j}, x_{2j}, \dots, x_{mj})$ inputs (food groups) and $Y_j = (y_{1j}, y_{2j}, \dots, y_{sj})$ outputs (nutrients intake). Suppose that x_{ij} ($i = 1, 2, \dots, m$) is the quantity of food group i consumed by household j (DMU $_j$) and y_{rj} ($r = 1, 2, \dots, s$) is the quantity of nutrient intake by

household j (DMU j) [26]. Therefore, the following DEA model can be used to measure nutrition intake efficiency.

$$\begin{aligned}
& \max \theta + \varepsilon \left(\sum_{i=1}^m S_i^- + \sum_{r=1}^s S_r^+ \right) \\
& s.t. \sum_{j=1}^n \lambda_j x_{ij} + S_i^- = \theta^* x_{i0} \quad i = 1, 2, \dots, m \\
& \quad \sum_{j=1}^n \lambda_j y_{rj} - S_r^+ = y_{r0} \quad r = 1, 2, \dots, s \\
& \quad \lambda_j \geq 0 \\
& \quad \varepsilon \geq 0
\end{aligned} \tag{2}$$

Where the optimal θ^* represent the efficiency in input-oriented model; S_i^- , S_r^+ are the slacks of inputs and outputs, respectively; n represent the number of DMUs; j represent indexes for DMUs; m represent the number of inputs; $i = 1, 2, \dots, m$ represents an index for inputs; s represents the number of outputs, $r = 1, 2, \dots, s$ represents an index for outputs and λ is called the intensity vector. DMU $_0$ is efficient if and only if $\theta^* = 1$ and $S_i^- = S_r^+ = 0$ for all i and r . DMU $_0$ is weakly efficient if $\theta^* = 1$, and at least one of the slack is non zero (i.e. $S_i^- \neq 0$ or $S_r^+ \neq 0$ for some i or r).

2.4. Associated factors with nutrient efficiency: A generalized linear model

Table 2 shows variables that are chosen as potential determinants of nutrient efficiency based on the related literature review.

Table 2. Definition of variables used in GLM

Variable			Average		Percent	
			Rural	Urban	Rural (= 1)	Urban (= 1)
HH-Social	HH-Age	Age of household head in townships	50.9	49.6	-	-
	HH-Educated	The education of households head (educated = 1, otherwise = 0)	-	-	38.5	23.4
	HH-Sex	Sex of household head (man = 1, otherwise = 0)	-	-	88.4	89.3
	HH-Marital	Marital status of household head (HH who is married = 1 and otherwise = 0)	-	-	87.6	87.7
	N	Household size	3.6	3.4	-	-
	N-Student	The number of students in household	0.9	1.0	-	-
	N-Educated	The number of educated in household	2.8	3.1	-	-
	N-Employee	The number of employees in household	1.3	1.1	-	-
	HH-Employee	The employee status of household head (employing = 1)	-	-	95.2	95.0
	HH-Keeping	1 if female headed household is housewife, 0 if otherwise	-	-	98.9	99.1
HH-Economical	SH-Agriculture	Agricultural income share of households incomes	-	-	13.5	3.0
	SH-Food	Household food share of total expenditure	42.6	33.8	-	-
	DDS ^a	Food diversity (percentage of consumption goods of total 167 goods)	9.1	8.2	-	-
HH-Assets	Home	Household some status (private home = 1)	-	-	93.7	82.2
	S-Home	Home area (m ²)	89.1	101.9	-	-
	Machine	Household machine status (private machine = 1)	-	-	23.7	36.3
HH-Cultural	Azeri language	Township in ethnic Azeri language = 1, otherwise = 0	-	-	14.2	14.5
HH-Geographical	Capital city	Capital cities = 1, otherwise = 0	-	-	10	9.7
	Sea-Cities	Townships on the edge of the sea	-	-	10.6	10
	Tropical-Cities	Townships in the tropical regions = 1, otherwise = 0	-	-	14.8	14.8

^a DDS was calculated through HDDS (number of different food groups consumed over a given reference period) [23]. Firstly, the HDDS variable is calculated for each household. The value of this variable range between 0 and 12. Secondly, the average HDDS indicator is calculated for the sample population [27].

In the second stage of the analysis we used a censored regression (Tobit) to assess associated factors with nutrient efficiency:

$$\theta^i = \sum_{i=1}^R \beta_i W_i + \varepsilon_i \quad (4)$$

Where θ^i is the efficiency calculated from solving the mathematical programming problem 2 above, and used as a dependent variable, and W is a $(R \times 1)$ vector of independent variables related to attributes of the households in the townships. The dependent variable has two values as follows:

$$\theta^i = \begin{cases} \theta^* & \text{if } \theta^* > 0 \\ 0 & \text{if } \theta^* \leq 0 \end{cases} \quad (5)$$

where θ^* is a latent variable. Table 2 summarizes the statistical description of all factors used in this study.

3. Results and discussions

3.1. Nutrient intake efficiency analysis

In the first step, we calculated the average nutrition intake of individual in the urban and rural areas. There is a significant difference among all nutrient intakes between rural and urban areas. As seen in Table 3, the nutrient intake of individual in the rural areas was greater than in urban areas, except for vitamin A and vitamin C. The calorie intake of individual is 3615/Cal/per person in rural areas, while the intake of this macronutrient is 3280/Cal/per person in urban areas.

Table 3. Nutrient intake in rural and urban areas in Iran.

Nutrition	Rural areas				Urban areas				Difference
	Average	S.E.	Max	Min	Average	S.E.	Max	Min	
Calorie	3615	258.3	5178	1859	3280	239.3	5455	1553	-6.92***
Protein	94	18.05	125	55	82	15.06	116	49	-10.7***
Calcium	747	145.4	1022	422	689	134.5	1013	412	-8.02***
Iron	23	4.58	33	14	21	4.24	31	13	-6.74***
Vitamin A	1558	403.9	2606	675	1718	402.4	2412	799	4.84***
Vitamin C	96	26.13	675	54	103	25.18	153	49	2.87***

*** Indicates significance at 1% level.

Also, the amount of intake of all macro-micro nutritions is really important to be healthy, the source of acquiring this nutrition is substantial. Table 4 shows that the average foodstuff consumption of rural households is greater than urban areas. According to the results, the average

consumption of all food groups in the rural area was greater than the urban area. As Table 4 shows, the most important part of difference between calorie intake between individual in rural and urban areas is related to the consumption of cereal.

Table 4. Descriptive statistical analysis of inputs.

Food groups	Urban				Rural				Difference
	Average	S.E.	max	Min	Average	S.E.	max	Min	
Cereal	50	14.87	91	29	62	18	102	33	-9.4***
Vegetable	5.5	3.07	13	1.7	9	4.69	21	1.6	-7.2***
Fruits	4.2	1.34	8	2.1	9	3.07	19	4	-4.6***
Dried fruits	1.8	0.83	4	0.63	1.7	0.99	5	0.56	0.32
Dairy products	13	3.32	19	6.7	16	4.58	25	7	-9.6***
Legumes	0.47	0.33	2	0.08	0.6	0.39	2	0.08	-3.1***
Fish meat	2.8	0.41	4	1.8	3	0.49	4	1.7	-4.5***
Poultry meats	22	4.68	33	13	25	7.62	45	13	-5***
Red meats	2.4	1.12	6	0.69	3	1.30	6	0.44	-0.86
Vegetable oils	16	3.74	27	9.5	18	4.90	30	9	-3.9***
Animal fats	2.9	0.89	6	1.4	3	0.84	6	1.6	-5.6***
Sweets	4.7	1.10	7	2.9	5	1.64	9	2.3	-6.3***
Spices	4.4	1.95	10	2.1	5	2.26	11	2.1	-4.3***
Beverage	0.46	0.26	2	0.15	0.44	0.17	1	0.11	-2.3***

The nutrient efficiency of all townships was estimated using DEA. Townships with score 100 had the best nutrient consumption efficiency. Then, the provincial score was calculated through averaging the efficiency score of townships within each province. Table 5 shows the average efficiency score of each province. The average efficiency score of some provinces including Alborz, East Azerbaijan, Chaharmahal and Bakhtiari, Kerman, Khuzestan, Qazvin, Tehran, Yazd and Zanjan have significant difference between rural and urban areas. This result may be related to the optimized food consumption of the households and also, the minimization of food waste.

Table 5. Townships with full efficiency in rural and urban area in Iran

Province	Rural	Urban
Alborz		
Ardabil		
Bushehr	Dashti and Deyr	
East Azerbaijan		Malekan and Varzaghan
Fars	Abadeh, Mehr and Neyriz	
Hamadan		Ranen
Hormozgan	Abu Musa, Parsian and Minab	Bastak and Khamir
Ilam		Darreh Shahr
Isfahan	Shahreza and Fereydunshahr	Dehaghan, Fereydan and Fereydunshahr
Kermanshah	Sahneh and Gilan-e-Gharb	Paveh and Gilan-e-Gharb
Khuzestan	Abadan, Bandar-e-Mahshahr,	Andimeshk, Ramshir, Shush and Shushtar

	Khoramshahr, Shadegan, Shushtar and Masjed Soleyman	
Kurdistan	Bijar	
Mazandaran	Savadkuh	Juybar, Savadkuh, Galugah and Noshahr
Semnan		
Sistan and Baluchestan	Nikshahr	Zahak and Konarak
South Khorasan		Darmian
Tehran	Eslamshahr	
West Azerbaijan	Bukan and Takab	Oshnavieh
Zanjan	Ijrood	Ijrood and Tarom

Rural and urban nutrient efficiency was compared by the province in the form of a map (see NEM in Fig. 2 and Fig. 3).

Fig.

2. Nutrient intake efficiency map (NIEM) in the rural area in Iran, 2016.

This map has been developed using GIS software, encompassing a broad range of applications using a combination of digital maps and geo-referenced data. Many rural townships had efficiency scores of less than 70%, which are even lower in the Northeast. North, East and North East townships had low urban nutritional efficiency, even lower than their rural areas. In central Iran,

rural areas were more nutrient efficient than urban areas. Khuzestan had the highest efficiency in both rural and urban area, followed by Fars, while Qom was the lowest. Comparison of two areas in Fig. 4 demonstrated that the average efficiency in the rural areas was higher than in urban areas among the majority of provinces in Iran. As can be seen in Fig. 4, the greatest gap in nutrient efficiency between rural and urban areas was in Alborz province.

Fig.

3. Nutrient intake efficiency map (NIEM) in the urban area in Iran, 2016.

The results indicated that a better-balanced food groups consumption was found in rural compared to urban areas.

Fig. 4. Comparison of the average of the nutrient efficiency in the provinces in both rural and urban area.

3.2. Benchmarks for 30 provinces in Iran

Benchmarks for each province to reach ONIE (Optimal Nutrient Intake Efficiency) provide the targets for Iranian households to balance expenditures and consumptions along with health protection. For better nutrient efficiency in households in Tehran, a densely populated capital city, households should decrease cereal consumption by 30% per month. To optimize foodstuff consumption (receiving the current nutrient intake) and to reduce households' expenditure in Tehran in comparison with other provinces where households have the better ONIE, households

should decrease, per person, the consumption of all food groups. The dietary pattern in some provinces was sub-optimal. Associated factors with nutrient intake efficiency

Associated factors with nutrient intake efficiency were determined in both rural and urban areas. Table 6 includes the estimated coefficients from the Tobit along with the z-statistics and shows differences between the two areas. Age of the household head was positively and significantly associated with nutrient efficiency in both rural and urban area. Households whose heads were educated had better nutrient efficiency than other households. The male-headed households had a lower nutrient efficiency than female-headed households in urban areas, while gender of the household head had no impact on nutrient efficiency in rural areas. Household size was directly and positively associated with nutrient efficiency only in rural areas. Dietary diversity was positively and significantly associated with the nutrient efficiency in both rural and urban areas, with the association stronger in the rural areas than in urban areas. Ethnicity was significantly and directly associated with nutrient efficiency. Azeri areas, the densely ethnic population in the northwest of the country, had a higher nutrient efficiency and lower food waste compared to other ethnicities. Tropical areas, such as Ilam, Khuzestan, Bushehr, and Sistan and Baluchistan, had higher nutrient efficiency than cold regions. Eventually, some factors including capital cities, the share of agricultural income and married head of household were inversely and significantly associated with nutrient efficiency in both rural and urban areas.

Table 6. Effective factors on nutrient inefficiency in the rural and urban areas

Table 6. Effective factors on nutrient inefficiency in the rural and urban areas					
Item		Rural	Z-Statistics	Urban	Z-Statistics
		Coefficient		Coefficient	
A. Variable					
HH-Social	HH-Age	-0.0080***	-2.46	-0.0023***	-2.81
	HH-Educated	-0.0031*	-1.96	-0.0027**	-2.06
	HH-Sex	0.0032	1.39	0.0013*	1.78
	HH-Married	0.0037*	1.62	0.0033*	1.73
	HH-Employee	0.0006	0.29	-0.0038**	-2.25
	HH-Keeping	0.0049**	2.24	-0.0082*	-1.74
	N	-0.1739***	-2.98	-0.0373	-0.61

	N-Student	-0.0107	-0.19	-0.0180**	-2.10
	N-Educated	0.1071*	1.68	0.0854***	4.20
	N-Employee	-0.0551**	-1.90	-0.1838***	-3.87
HH-Economical	SH-Agriculture	0.0031**	2.10	0.0034***	5.31
	SH-Food	-0.0063***	-3.44	-0.0096***	-4.47
	DDS	-0.0117***	-5.84	-0.0057***	-2.93
HH-Assets	Home	0.0029***	2.72	0.0006	0.06
	S-Home	0.0001	0.08	-0.0007**	-2.31
	Machine	-0.0012*	-1.71	0.0022***	3.02
HH-Cultural	Azeri language	-0.0559**	-1.88	-0.0869***	-3.17
HH-Geographical	Capital city	0.1342***	4.61	0.1868***	5.77
	Sea-Cities	0.0162	0.52	0.0461***	3.18
	Tropical-Cities	-0.0730**	-2.30	-0.0588*	-1.74
<i>B. Constant</i>	-	0.8692***	2.46	0.8014**	2.55

4. Results and discussions

Our work established the value of FOC and ONIE within optimizing frameworks for studying nutrient security. Empirically, the utility of using a combination of DEA and Tobit model is vindicated. A large data set to derive policy-relevant results can be used within our models.

The results showed that household dietary patterns depend on consumer food habits, knowledge of good nutrition, and the availability and accessibility of a variety of healthy and affordable food ingredients. Nutritional education increases knowledge of food combinations [28, 29], and as a result, food waste declines and the household nutrient efficiency increases. In this paper, an innovative approach was developed to identify the association between food combinations and nutrient efficiency in urban-rural areas in Iran using a two-stage approach. According to the descriptive results, nutrient intake of Iranian households in rural areas was greater than in urban areas. This result may be associated with higher agricultural and animal production by rural households [30, 31]. Rural households can easily access adequate food ingredients, especially raw ingredients, which help them access needed nutrients without extra payment.

In the first phase, the nutrient efficiency of households was calculated using DEA approaches. The results showed that the combination of food ingredients was not utterly optimal in all provinces in

both rural and urban areas and the high share of food ingredients are wasted (consumed but not needed.) Rural households had 30% nutrient inefficiency and urban households 35% inefficiency in the food groups' consumption. Nutrient inefficiency was lower in rural areas than the urban areas, and generally, it confirms that the status of the availability of healthier foodstuff combinations in the rural areas was better than in urban areas. The provinces of Qom and Semnan had the lowest efficiency in both rural and urban areas. The highest rural and urban inefficiency scores were in the provinces of Fars, Khuzestan, and Hormozgan. These high scores may be associated with a high level of education in these provinces contributing to choosing the best combination of food ingredients.

Most of the cities face nutrient inefficiency, especially in the northeast of the country. Households could increase their nutrient intake by ameliorating food group combinations. Food combinations in high-efficiency areas could be used as a guideline to improve nutrient status in low-efficiency areas. For example, food ingredient combination in Khuzestan province as the better location in terms of nutrient efficiency can be monitored and addressed by the adjacent provinces for improving households' nutrient status.

Patterns of food consumption waste food ingredients in Iran. The nutrient status of Iranian households can be improved by decreasing their food expenditure without changing their nutrient intake. This condition could allow the country to save strategic food ingredients, decrease food waste and, eventually, decrease the budget deficiency as one of the most substantial challenges, nowadays, in Iran, because this country is one of the biggest importers of food ingredients worldwide.

The direct association between the age of head of household and nutrient efficiency suggest that older heads have more experience in combining food ingredients and also, their knowledge and

capability of food combinations lead to increasing nutrient efficiency [32, 33]. Some studies contended that elder heads have an adequate ability to food money management along with experience better dietary quality [34] and reduce food waste.

Higher education of household head is associated with increasing the nutrient efficiency of food consumption, and so food waste is reduced. This result contradicts a study in Suriname which found both adequate and excessive consumption increased with the higher degree of urbanization, level of education and income [4].

Households whose heads were female had greater nutrient efficiency in urban areas. A female head may have more experiential knowledge of combining different combinations of food, as they play an essential role in the nutrition of children and other members [35]. Some studies found that male-headed households have higher nutrient security [36, 37]. However, other studies found that male-headed households are more nutrient secure [32]. These results are attributable to the lower incomes and lower access to resources of female-headed households. Once the confounding causal influence of income and economic status are controlled, female heads have higher nutritional efficiency and they are able to control food waste more efficient than male heads.

Household size had a direct and significant association with the nutrient efficiency in rural areas. Due the larger size of rural households, they endeavor to use their food ingredients appropriately and completely, and therefore, the amount of food waste is lower than in smaller households. The association between household size and food consumption has been found in some studies whether significant positive [30, 32] or significant negative association [31, 38].

The share of income from agriculture is inversely associated with nutrient efficiency. When rural households access easily adequate food ingredients through agricultural production, they waste

their resources. In fact, rural dwellers are confident that they always access the needed raw ingredients [39] and do not intend to control their consumption and food waste.

An increase in the number of different food groups consumed provides a quantifiable measure of improved household food access and consumption. In general, any increase in household dietary diversity reflects an improvement of the household's diet quality [23]. An increase in the number of consumed food groups will lead to increased nutrient intake efficiency, eventually increasing nutrient security. In contrast with our findings, some studies contended that living in urban areas is associated with higher dietary diversity and also higher fruit and vegetable intake in low- and middle-income countries.

Azeri people had more nutrient efficiency than other ethnicities in Iran. This result suggested that this population has a high ability in combining food ingredients in optimized level for achieving nutrient efficiency compared to other ethnicities. As a geographical pattern of food consumption demonstrated, people of Azeri ethnicity, living in the northwest of Iran, can prepare different kinds of food through distinct food ingredients leading to a decrease in food waste.

Geographical location of a province was significantly associated with nutrient efficiency. Living in the capital city led to an increase in food waste and simultaneously the decrease of the NIE in both rural and urban areas. Household income in Tehran is higher than other locations in Iran, so there is no felt need to optimize food ingredients. Marques et al. [40] found geographical location is a key factor in controlling food waste and recycling systems.

Amount of food waste is directly associated with the type of knowledge of people in different locations. According to the nutrient culture of people in seaside cities, the NIE of households who are living in these cities is lower than those who are living in other locations. The abundance of

food, plentiful local and traditional foods, diet diversity and access to adequate food ingredients may be the main reasons for this negative association in these seaside cities.

Ultimately, some of countries, especially developing countries, face prevailing food insecurity due to the lack of accessibility to adequate resources and also enough foods [41]. The results of such studies can be used to determine the accurate consumption of food resources, decrease food waste, prevent from destruction of more resources for gaining more foods, and finally contribute people to save their income and reduce their expenditure.

As some international reports showed, the best combination of food ingredients is really important among some countries such as African countries because most of these countries faced the huge number of hunger and food insecure population [42] and through the same models, many poor African countries can better address the prevalence of undernourishment by using their available limited budget optimally according to the methodology presented in our paper. Totally, understanding socio-economic determinants of food efficiency is a key component of developing policies that will contribute the country to maintain its resources through controlling food waste. For this aim, a comprehensive study of nutrient efficiency through sophisticated techniques will help policymakers to find the lowest cost approaches for determining the best food baskets. This study has implications for policy most immediately within Iran. More broadly the results could be generalizable for other MENA countries, and also be applicable with further country-specific empirical work to other economies in the developing world that have income levels and degree of urbanization and geographical distribution like those of Iran.

Although consumers in developed and high-income countries have been identified as the biggest single contributor to food waste [43], our study suggested that this claim is also the case in developing countries. Further studies are needed to investigate the NIE and calculate the percent

of food waste in different regions, cities and countries. Future studies should examine how households in different provinces with a high nutrient efficiency allocate their food ingredients to food preparation and how they control and reduce food waste. That information could aid the formulation of new policies to promote higher nutrient efficiency, control the consumption of strategic and staple food ingredients and reduce food waste.

5. Conclusions

The food patterns in the provinces with a high score of nutrient efficiency could be used as a guideline for other parts of the country by the government. But households also need monetary resources to access healthy foods, which must be available at reasonable prices in local markets. According to the efficiency map drawn out of our empirical analysis, policies should be directed to specific geographical area-based households, especially in the Northeast, where the households face the lowest level of nutrient efficiency and the highest rate of food waste due to inappropriate food patterns. As results showed, Socio-economic and cultural factors are associated with nutrient intake efficiency. Educating households regarding the correct combination of food ingredients to increase nutrient knowledge is necessary. The diffusion of such education could be done by broadcasting TV commercials about appropriate dietary patterns and the dangers of eating the wrong combinations of food groups. Investment in primary education and including nutrition education may increase nutrient efficiency in the long term. Also, the association of geographical factors can be considered as an important dimension in prescribing a health policy because being in tropical cities is associated with the greater nutrient efficiency while the story in capital city and also, coastal cities is completely different. Designing different training packages of food combinations, focusing on the exact reasons of the low level of nutrient intake efficiency in such

areas and finally, constructing the specified number of urban zones based on the similar nutrient intake efficiency (or close efficiency) may help policy makers and planners to save national and urban resources without declining people's nutrient level.

This study has several limitations as other studies confront. Verification of the results is directly associated with the accuracy of filling out the questionnaires. Another limitation of this study is the need to disaggregate the large data set that included all counties and provinces in Iran. The use of the food composition table suggested by the NNFTRI could be a limitation, because some of the commodities used by Iranians are not included in the table, especially imported commodities because the nutrient contents of these commodities are different.

Declarations

Ethics approval and consent to participate: Not applicable because the data and information was achieved the free available dataset of Iranian statistical center

Consent for publication: Not applicable.

Availability of data and materials: The datasets generated and/or analyzed during the current study are available in the [the website of Iranian statistical center] repository, [<https://www.amar.org.ir/>].

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Authors' contributions:

- Mohammad Reza Pakravan-Charvadeh: Supervision, Formal analysis, Methodology, Writing-Original draft preparation.
- Cornelia Flora: Validation, Resource, Data Mining.

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