

Is Nutritional Functional Diversity In The Rural Food And Nutrition System Associated With Food Security And Nutrient Adequacy? A Case Study of Rural Areas of Zahedan City, Iran

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2 **with Food Security and Nutrient Adequacy? A Case Study of Rural Areas of Zahedan**
3 **City, Iran**

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10
11 **Abstract**

12 **Background:** An often overlooked problem in food and nutrition systems analysis is assuring
13 adequate diversity of nutrients for healthy diet. Nutritional functional diversity (NFD) is a
14 metric that describes diversity in providing nutrients from farm fields to markets and all the
15 way to the consumption level. The objective of this study was to determine the NFD score at
16 different stages of rural food system, from Household's agricultural and home production,
17 processing, to purchased food and diet, and to explore the association between NFD and
18 nutrient adequacy, food security and anthropometric indicators.

19 **Methods:** A cross sectional study was conducted on 321 household's in 6 villages of Zahedan
20 district. The NFD score was measured at three subsystems (production, processing and
21 consumption) of food and nutrition system. To assess the association between NFD and food
22 and nutrition indicators, such variables as household's food security, mean adequacy ratio
23 (MAR), and anthropometric indicators of household's head were also measured. Different
24 bivariate and multivariate statistical techniques were applied to study the association between
25 variables.

26 **Results:** In rural food and nutrition system, the foods purchased from the city play the main
27 roles in the household's NFD score. Their role in NFD was twice that of the foods purchased

۲۸ from village. As well, NFD score of homestead production and household's processing were
۲۹ found to be five times less than those of foods purchased from cities. The food insecure
۳۰ household's had significantly lower NFD scores of food purchased from the city as well as
۳۱ higher NFD score for purchased foods from the rural market and native plants consumption.
۳۲ Additionally, a strong and positive relationship was observed between NFD of household's
۳۳ diet with that of household's MAR. Of note, no significant association was found between
۳۴ NFD score of homestead production and processing and food insecurity, MAR, and
۳۵ household head anthropometric.

۳۶ **Conclusion:** NFD score can serve as a good indicator in assessing the food system, which can
۳۷ also be used by policy makers to identify gaps in the local food and nutrition system, and plan
۳۸ appropriate interventions for improving diversity and addressing food insecurity.

۳۹ **Keywords:** Nutritional functional diversity, food system, food security, Nutrient adequacy,
۴۰ rural, Iran

۴۱ **Background**

۴۲ The trend of hunger, after decades of steady decline, has been slowly on the rise worldwide
۴۳ since 2014 [1]. More than 690 million people in all over the world are still hungry and 2
۴۴ billion people have no regular access to safe, sufficient, and nutritious food, so they are
۴۵ suffering from moderate to severe level of food insecurity [2]. Given these conditions, the
۴۶ goal of achieving the zero hunger by 2030 seems unrealistic [2, 3]. COVID-19 pandemic,
۴۷ disproportionate slowdowns or downturn economy, climate variability, and conflict are
۴۸ currently exacerbating these trends [2, 4].

۴۹ While receiving sufficient calories is still considered as a major challenge, an often overlooked
۵۰ problem in food and nutrition systems is having an access to adequate diversity of nutrients
۵۱ for providing healthy diet and life [5]. It is well recognized that hidden hunger and

malnutrition have several roots in dysfunctional food and nutrition systems that is accompanied with nutrient inadequacy of diet, especially in poor communities [6-9].

Diversity through a food and nutrition systems' approach could be considered as a driver for causing a change by improving direct interactions between food producers and consumers, and by increasing the quality of diet, and fighting against the triple burden of malnutrition (undernourishment, micronutrient deficiencies, and overweight and obesity). Such approach can also be associated with lower rates of food insecurity and mortality [10-17].

One of the main gaps in food diversity research is that most of them have deal with food diversity in one or two subsystems and a holistic perspective which encompass food diversity in all subsystems of food and nutrition system is missing [18, 19]. Various indicators have been used to assess food diversity in these studies. Therefore, the focus has been mainly on the consumption rather than food provision, and little is known about how diversity is transmitted to dietary diversity at the household level [20]. For this purpose, proper metrics are required to assess the ongoing food policy at both national and regional levels of food and nutrition system, in order to modify or design appropriate interventions for its improvemet. nutritional functional diversity (NFD) is a metric firstly introduced by Remans et al. [21], used to describe diversity in available nutrients from farms to markets and all the ways directed to the consumption level. NFD shows nutritional differences and variations in all groups of foods and food items that are not captured by a food variety score and/or by a diet diversity score [22]. Notably, NFD score can be used at any level (from farm to diet), because it is based on the nutritional composition of foods for 17 nutrients that paly key roles in human beings' health status [21]. Therefore, NFD score can reflect the potential of a food system in meeting the nutritional requirements of a population as well as the link among subsystem diversity, food security, and health. This issue has not been well-addressed in the studies conducted on the food and nutrition systems in Iran.

٧٧ This study aimed to determine the NFD score at different subsystems of rural food and
٧٨ nutrition system from household's agricultural and homestead production and processing, to
٧٩ purchasing food and its diet. Moreover, this research aimed to explore the association of NFD
٨٠ score of rural food and nutrition system with nutrient adequacy, food security, and
٨١ anthropometric indicators in rural communities of Zahedan city, in the Southeast of Iran.

٨٢ **Conceptual framework**

٨٣ NFD indicator is a new concept in food and nutrition research and data on its linkages with
٨٤ food and nutrition security and the related dimensions are still scarce [20, 21]. NFD indicator
٨٥ can be applied to describe the diversity of food at different stages of the food and nutrition
٨٦ system. Up to now, little is known about food diversity at different stages of rural food and
٨٧ nutrition systems and the way of its transmission to dietary diversity at the household level
٨٨ [20, 23]. Remans et al. in their research proposed potential determinants of NFD, including
٨٩ agro-ecological, socio-economic, and socio-cultural factors at both farm and village in
٩٠ different seasons as well as the possible effect of NFD score on food and nutrition indicators,
٩١ including food insecurity, diet diversity, anthropometry, and nutrient deficiencies [21]. Based
٩٢ on another study by Bellon *et al.*, there is a triangular connection among three facets of
٩٣ diversity on farm, market and diet [24]. Moreover, endogenous connections exist between on-
٩٤ farm diversity and dietary diversity through self-consumption, between on-farm diversity and
٩٥ market diversity through sale, and between dietary diversity and market diversity through
٩٦ purchase. Besides, these are all affected by some confounding factors such as land quality and
٩٧ tenure, climatic variability, different types of markets, and ethnicity [24].
٩٨ Our conceptual framework was based on a combination of the two above-mentioned concepts
٩٩ (Figure 1). We measured NFD score in the food and nutrition system of rural households.
١٠٠ Correspondingly, food and nutrition system of rural households is a local food system that

1.1 gathers all the elements and activities related to the production, processing, distribution,
1.2 preparation, and consumption of food, as well as the outputs of these activities, including food
1.3 security, socio-economic, and environmental outcomes [25]. This study paid a specific
1.4 attention to NFD score in rural food and nutrition system and its association with nutrition
1.5 and health outcomes of food systems. We hypothesized that in rural food and nutrition
1.6 system, NFD on farm, homestead production, and household's processing are linked through
1.7 the following two routes: on market through sale and on dietary diversity through self-
1.8 consumption. Agro-ecology (including climatic, soil types and conditions, water quality,
1.9 greenhouse gas emissions, native species diversity, and distribution of species), socio
1.10 economic condition (including having access to diversity of seeds, access to fertilizers, access
1.11 to knowledge, and access to markets), and socio cultural factors (including cultural
1.12 preferences for species and subspecies, and multiple purposes and advantages of crops) can
1.13 affect NFD on-farm and home products. Homestead production of diverse foods can play
1.14 important roles in providing enhanced food supply and increased dietary diversity. Various
1.15 studies have previously shown that combining home garden and poultry production system
1.16 could improve food insecurity, malnutrition, and anemia among children and women [26-28].
1.17 Market NFD was indicated to be linked with dietary NFD through purchase (from city,
1.18 village or as a gift or other places), which is influenced by a set of factors, e.g. market access
1.19 and place, links to different types of markets, availability of infrastructure, food price,
1.20 household's income, ethnicity, and knowledge. In this regard, market linkages would enable
1.21 households to consume diverse diets through both the demand via enhancing households'
1.22 ability to sell part of their produce and supplying a side via making more diverse and
1.23 nutritious foods available to households, especially in the lean season [23, 29] . In rural areas
1.24 of the developing countries worldwide, markets often have poor functions. Rural markets are
1.25 highly variable in what they provide and having any access to urban markets is difficult for

low-income households due to the lack of road infrastructure and transportation roads [30-32].

Therefore, NFD score in rural food and nutrition system affects food and nutrition indicators, including food and nutrition security, dietary quality, anthropometry, and nutrient deficiencies, which are themselves affected by some factors such as family size, age, sex, and educational level of household's head, household's income and welfare, and distance from market. The relationship between NFD scores at different subsystems of rural food and nutrition system with each other and with food and nutrition indicators, does not seem to be a simple linear relationship. Accordingly, this can be complex, depending on different regions and various factors.

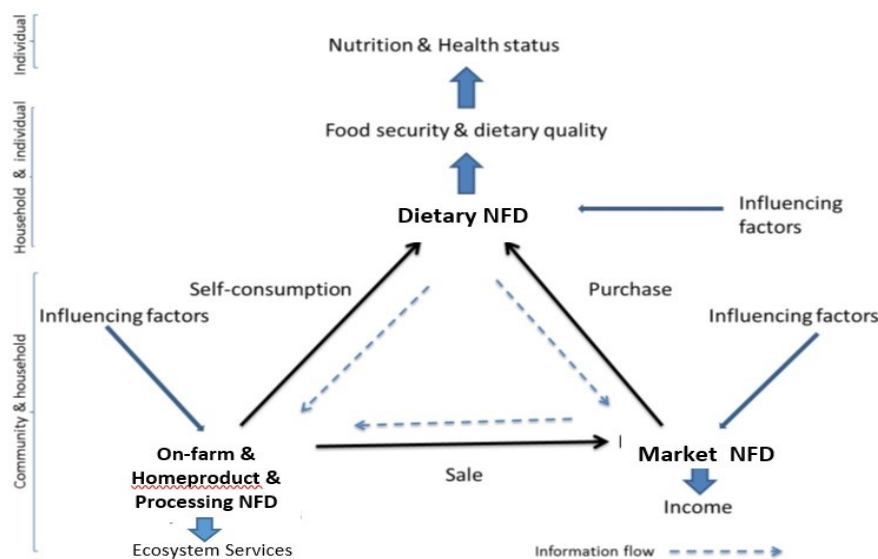


Figure 1. Conceptual framework on the linkage among the farm, homestead production and household's processing NFD, as well as the purchased food and dietary NFD in rural food and nutrition system [24]

Methods

Setting and study design

۱۴۲ This population-based cross sectional study was conducted in Zahedan rural communities
۱۴۳ from April to July 2019. Zahedan is one of the main counties of Sistan & Baluchistan
۱۴۴ Province, located in the Southeast of Iran, with long, sweltering, arid, and clear summers and
۱۴۵ cold, dry, and mostly clear winters; with a little amount of rain throughout the year [33].
۱۴۶ Based on the "food security information and mapping system in Iran" survey [34] , this
۱۴۷ province has the highest food insecurity rate in the country (58.8 percent) [35], where 12.8%
۱۴۸ and 20.7% of children aged under five years old are suffering from underweight and stunting,
۱۴۹ respectively [34]. Zahedan county is subdivided into the following three administrative
۱۵۰ districts: Central, Kurin, and Nosratabad. Two villages from each district were randomly
۱۵۱ selected. According to the Cochran's formula and based on the rural household's population,
۱۵۲ sample size of this study was determined as 320 household's.

۱۵۳ **Data collection**

۱۵۴ Before starting the fieldwork, 12 interviewers who were fluent in local language of that
۱۵۵ region, i.e. Baluchi, were recruited from community health staff members. Thereafter, they
۱۵۶ were trained in a two-day workshop in order to be coordinated and to reduce interpersonal
۱۵۷ variation in data collection process. The required data were collected through face-to-face
۱۵۸ interviews with mothers (assisted by their husbands).

۱۵۹ **Measurements**

۱۶۰ **Household's demographics:** Demographic information and socioeconomic variables,
۱۶۱ including age, gender, educational level, and employment of all household's members,
۱۶۲ household size, household's subsidy supports, and household's facilities were collected using
۱۶۳ the validated questionnaire of Statistical Center of Iran [36] . To calculate household's
۱۶۴ welfare index, the household's facilities and equipment were recorded and then weighed
۱۶۵ between 0-10 by the research team, based on price, necessity, and importance and total score
۱۶۶ for household's were finally computed.

167 **Household's agricultural and homestead production, and processing:** Household's were
168 asked to report details of their household's agricultural and home production and processing
169 during the last 12 months using a questionnaire consisted of the following 3 sections: 1)
170 existence of home-garden/ household's processing in the house as well as the type and
171 amount of produced/processed product(s), 2) the presence of livestock/poultry in the
172 household's, and its type and quantity, and 3) ownership of agricultural land and type of any
173 crop(s) cultivated.

174 **Household's dietary intakes and food sources:** Household's dietary intakes and having
175 access to different types of markets were recorded by the trained community health workers
176 by completing 24-hour diet recalls for two non-consecutive days in one week. All foods and
177 dishes and their ingredients consumed by the household's were recorded according to the
178 main meals and snacks and also according to the source of each food (purchased from any
179 place, own production, and/or gift). Any foods consumed by the household's were weighed
180 using a calibrated digital scale with a precision of ± 1 gram. (Kitchen Scale EK8450, Camry
181 Electronic Ltd, Guangdong, China).

182 Nutritional values of the items of the consumed food were calculated using the Iranian food
183 composition table [37] and the USDA Food Data Central [38]. Considering the dietary
184 reference intake (DRI) for energy, protein and limiting micronutrient in the region, including
185 vitamin A, calcium, iron, and zinc [39, 40], adequacy of household's dietary intake was
186 estimated by calculating household's adult male equivalent units (AMEs) using the method
187 introduced in a study by Weisell *et al.* [41]. AMEs were computed according to the energy
188 requirement of an adult male aged between 18 and 30 years old with moderate level of
189 physical activity [42, 43]. Number of the present household's members and guest(s) per each
190 meal based on their age and sex was taken into account, and AME for each meal was then
191 calculated separately. Daily meals, including breakfast, lunch, dinner, and snack(s) were

192 calculated with relative weights of 0.16, 0.43, 0.30, and 0.11, for each meal, respectively. This
193 weighting value was then applied to each meal representing the energy contribution of that
194 meal to the daily energy intake, which is an important factor to be considered when the food
195 consumed through the day is measured and one that is often neglected [41]. Finally, the
196 adequacy of household's dietary intakes was assessed by dividing household's dietary intakes
197 for energy and micronutrient to household's AME. As well, nutrient adequacy ratio (NAR)
198 was calculated for each nutrient as the percent of the nutrient meeting, the DRI for energy,
199 protein, and 10 micronutrients, named as iron; zinc; calcium; vitamins A, C, B1, B2, B3, and
200 B12; and folate. The mean adequacy ratio (MAR) of the diet was calculated by the addition of
201 the 12 NARs and then divided by the number of nutrients [44].

202 **Nutritional Functional Diversity (NFD) score:** NFD is based on the functional differences
203 of available foods in a food and nutrition system, in a way that higher scores indicate a more
204 diverse diet. The NFD score of food and nutrition system is usually measured at three levels
205 as follows: 1) in production subsystem via a researcher-made questionnaire by measuring
206 various annual household's agricultural and home products, 2) during processing subsystem
207 using a questionnaire by measuring various annual household's processing levels, and 3) in
208 consumption subsystem by obtaining household 24-hour diet recalls for two non-consecutive
209 days, which also included some questions on place of purchasing/obtaining the food items and
210 their prices.

211 In this study, NFD score was calculated according to the four main steps described in a study
212 by Luckett *et al.* [20]: firstly, a food–nutrient matrix was created. In this matrix, each row
213 contained one of the food items in rural food system, and each one of these columns
214 contained a nutrient, so each cell of the matrix gave the nutrient content of each one of the
215 food items. In all levels of rural food and nutrition system, after excluding foods with
216 negligible nutritional value (e.g. salt and spices), 133 food items were selected to be included

۲۱۷ in the final analysis. In this regard, the food–nutrient matrix was composed of energy and the
۲۱۸ following sixteen nutrients: protein, fat, carbohydrate, fiber, vitamin A, vitamin D, vitamin C,
۲۱۹ thiamin, riboflavin, niacin, folate, vitamins B12, Ca, K, Fe, and Zn. Nutritional values were
۲۲۰ calculated per 100 g of the foods obtained from the Iranian food composition table [37] and
۲۲۱ the USDA Food Data Central [38] . Thereafter, the nutrient values in the food matrix were
۲۲۲ standardized in the following two ways: 1) they were divided by the recommended dietary
۲۲۳ allowances (RDA) for adult male subjects aged between 18 and 30 years old , and 2) these
۲۲۴ were then standardized to have mean=0 and SD=1. Secondly, the food–nutrient matrix was
۲۲۵ converted into a food–food distance matrix. Finally, the distance matrix was used to produce a
۲۲۶ cluster diagram, called a dendrogram, which was then used to calculate the NFD score.

۲۲۷ **household food security:** Household’s food security status was assessed by the household
۲۲۸ food insecurity access scale (HFIAS), which was validated for Iranian population [45]. This
۲۲۹ questionnaire is consisted of nine Likert-type questions on a four-week recall period. The
۲۳۰ respondent was firstly asked an occurrence question, as whether the condition in the question
۲۳۱ happened in the past four weeks (yes or no). In this regard, if the respondent answered “yes”
۲۳۲ to this occurrence question, frequency-of-occurrence was then asked to determine whether the
۲۳۳ condition happened rarely (once or twice), sometimes (three to ten times) or often (more than
۲۳۴ ten times) for him/her in the past four weeks. Of note, the HFIAS categorized households into
۲۳۵ the following four levels of food insecurity: food secure, mild, moderate or severe food
۲۳۶ insecure [46].

۲۳۷ **Anthropometric indicators:** At this stage, body weight and height of household’s head and
۲۳۸ his spouse were measured using a digital scale (Seca, Germany) and body mass index (BMI)
۲۳۹ was then calculated as weight (kg)/height (m²). Weight status of those aged between 19 and
۲۴۰ 60 years old was classified into one of the following classes: underweight (BMI<18.49),
۲۴۱ normal weight (18.5 – 24.9), overweight (25–29.9), and Obese (>30 Kg/m²) [47, 48]. In older

242 individuals (≥ 60 years old), BMI cut offs were defined as: ≤ 20.9 (wasting), 21 – 26.9
243 (normal), 27–29.9 (overweight), and ≥ 30 (obese).

244 Waist circumference was also measured with a precision of 1 mm in young and middle-aged
245 groups with a non-elastic tape at mid-way between the lowest rib and the iliac crest. As well,
246 abdominal obesity was defined as waist circumference more than 80 cm in women and 94 cm
247 in men [49].

248 **Statistical analysis**

249 The obtained data were expressed as mean \pm standard error (SE) or percentages. The
250 Kolmogorov–Smirnov test and histograms were used to test the normality of the interval/ratio
251 level variables. After confirming the non-normal distribution of the quantitative variables,
252 nonparametric Mann–Whitney and Chi square tests were both performed to compare the
253 outcomes between food secure and insecure household's.

254 Afterward, NFD scores were calculated using the R software. The association among NFD
255 scores at different levels of food and nutrition system with household's food security and
256 waist circumference of household's head were also analyzed by binary logistic regression.
257 Additionally, those of BMI of household's heads were analyzed by multinomial logistic
258 regressions. Moreover, the association between NFD score of food system with micronutrient
259 adequacy was analyzed by linear regression. Thereafter, Odds ratios (OR) and regression
260 coefficients with 95% confidence intervals (CI) were calculated for different regressions.
261 Notably, both unadjusted and adjusted models were used in these analyses.

262 In the adjusted model for food security, family size, household's income, household's under
263 additional subsidy plan (Except for national subsidy), distance from city, sex, educational
264 level and employment of household's head, and household's welfare index were considered
265 as the control variables. The control variables for the mean adequacy ratio model included the
266 similar variables to the food security model, but instead of sex, the variable of household's

head's age was used. In the adjusted model for BMI of household's head, the control variables of the mean adequacy ratio model and residence status were included as the control variables. For waist circumference of household's head, the control variables were as follows: family size, age, sex, and marriage status of household's head; household's income, household's under additional subsidy plan (Except for national subsidy); and household's welfare index. All the unadjusted models were run with no control variables. Data analysis was performed using Statistical Package for the Social Sciences (SPSS) version 16.0 (SPSS Inc., Chicago, IL, USA) software. A p value of 0.05 or less was considered as the statistical significant level.

Results

Household's demographic characteristics: Data were obtained from 324 household's selected from 6 villages (average 54 household's per each village). The average family size was 4.6 and 30% of the households had more than six members. About 70% of the household's heads were middle-age, 82% were men, more than 60% of them were illiterate or with primary educational level, and 40% of them were unemployed/housewife (table 1). In Iran, all household's at seven low income groups [50] are under the cover of the national unconditional cash transfer (UCT) program . This program covered 98.8% of the households studied and 23.5% received an additional help through Imam Khomeini Relief Committee.

Based on body mass index, about 52% of the household's heads had a normal weight, 16% were underweight, and 31% of them were overweight and obese. Of note, abdominal obesity was observed in 22% of the household's heads.

Household's food security status: The prevalence rate of mild and moderate/severe household food insecurity was 12.7 and 53.3%, respectively. Since mild food insecure household's constituted a small proportion of the sample and their socio-economic

291 characteristics, i.e. household income and household's head's employment status were similar
292 to those of the food secure household's, the two groups' participants were pooled in a single
293 group. The proportion of household food insecurity was found to be significantly higher in
294 those with greater household size, lower income, welfare index, and MAR, as well as
295 households whose heads were unemployed and had far distance from urban areas. No
296 significant difference was observed in anthropometric indices based on the household food
297 security status.

298 **NFD score of rural food and nutrition system:** Table 1 presents the results of the NFD
299 scores in different levels of rural food and nutrition systems from household's agriculture to
300 home production to purchasing food and diet. The NFD score for each household's at
301 different levels was calculated as percentage of the total NFD score in each village's food and
302 nutrition system. It was indicated that only 5.2% of the household's (n=17) had agricultural
303 products with the mean NFD score of 1.4. As well, the purchased foods more contributed to
304 household's nutritional diversity than home produced foods. The amount of food purchased
305 from city was twice the NFD score of foods purchased from village. About 50.9 % of the
306 household's received foods as a gift; however, this had a low contribution to NFD score.
307 Overall, lower NFD score at all levels consequently led to low levels of NFD score of the
308 household's diet. Moreover, the household's with moderate and severe levels of food
309 insecurity had significantly lower NFD scores of food purchased from the city as well as
310 higher NFD score for purchased foods from the rural market and native plants consumption.

311 **NFD and relationship with food security:** No significant association was found among NFD
312 scores of home food production and household's processing and household food insecurity
313 before and after adjusting the covariates, including family size, household's income,
314 household's under additional subsidy plan (Except for the national subsidy) , distance from

310 city, sex, education level and employment of household's head, and household's welfare
316 index (table 2).

317 NFD score of purchased foods from city was 8.4% lower in food insecure household's which
318 after adjusting covariates, reduced to a 7.2% decline. NFD score of food purchased from
319 village had a 4.5% increase in food insecure household's and after controlling the covariates,
320 this effect became even stronger (5.1%). Notably, with one a unit increase in NFD score of
321 native plants, the odds of being food insecure increased by 31.1%; however, this relationship
322 was not significant in the adjusted model (table2).

323 **NFD and relationship with mean adequacy ratio:** There was an inverse association among
324 NFD scores of home production and household's food processing and household MAR,
325 although it was not significant. An inverse and strong association was also found between
326 NFD score of food purchased from city with household MAR, even after adjusting covariates.
327 Additionally, a strong and positive relationship was observed between NFD of household's
328 diet (90.4% and 71.4% in the unadjusted and adjusted models, respectively) and household's
329 MAR (table3).

330 **NFD and relationship with anthropometric indicators:** There was an inverse association
331 among NFD score of home production and household's food processing and BMI and waist
332 circumference of household's head; however, this relationship was not significant (Tables 4-
333 5). A significant association was also found between the NFD score of food purchased from
334 city and abdominal obesity of household's head, in a way that the odds of being in
335 abdominally obese category increases by 5.8% with one unit increase in NFD; however, this
336 effect faded out after adjusting covariates. Notably, no significant association was found
337 between NFD score of rural food and nutrition system and BMI of household's head.

338 Table1. Characteristics of household's included in the study, Zahedan rural areas

339

Variables	household's food security status			
	Total household	FS ¹	FI ²	p-value [†]
	(n=321)	150 (46.7%)	171 (53.3%)	
	Mean (SE)	Mean (SE)	Mean (SE)	
Family size (persons)	4.64 (0.11)	4.28 (0.15)	4.98 (0.16)	0.004
Age of household's head (years)	43.57 (0.82)	43.72 (1.39)	43.45 (0.95)	0.235
Household's income (rial ³)	10309304.6 (573032.7)	13361259.0 (994321.5)	7644593.8 (565466.2)	<0.001
Household's income without cost of subsidy (rial ³)	7783696.4 (564935.8)	10957500.0 (982080.1)	5008812.5 (540812.1)	<0.001
Village distance from city (Km)	68.90 (1.27)	64.76 (1.65)	72.77 (1.88)	0.006
MAR ⁴	67.43 (0.75)	69.50 (1.11)	65.74 (1.01)	0.009
NFD ⁵ household's agriculture, (n=17 household's) (5.2%)	1.4 (0.5)	-	-	-
NFD of homestead production,(n= 145 household's) (44.8%)	3.72 (0.20)	3.5 (0.34)	3.83 (0.26)	0.415
NFD of household's food processing, (n=141 household's) (43.5%)	3.69 (0.25)	3.57 (0.36)	3.77 (0.35)	0.966
Food purchased from city, (n=311 household's) (96%)	15.92 (0.34)	17.58 (0.47)	14.53 (0.48)	<0.001
Food purchased from village, (n=277 household's) (85.5%)	6.93 (0.37)	6.05 (0.53)	7.72 (0.51)	0.021
NFD of Received gift, (n=159 household's) (50.9%)	3.24 (0.32)	2.65 (0.41)	3.62 (0.48)	0.374
NFD of Native plants, (n=208 household's) (64.2%)	1.23 (0.08)	0.98 (0.12)	1.40 (0.12)	0.029
Household's dietary, (n=321 Household's) (100%)	16.28 (0.19)	16.62 (0.31)	16.00 (0.25)	0.280
	n (%)	n (%)	n (%)	p-

					value ^{††}
Household's Welfare index	Low	106 (32.7)	42 (40)	63 (60)	0.002
	Medium	107 (32.7)	41 (39)	64 (61)	
	High	111 (34.3)	66 (60)	44 (40)	
Residence status	Ownership	249 (77.7)	117 (47)	132 (53)	0.775
	Rent/other	71 (22.3)	32 (45.1)	39 (54.9)	
Household's under additional subsidy plan (excluding the national subsidy)	Yes	79 (23.5)	32 (42.7)	43 (57.3)	0.421
	No	248 (76.5)	118 (48)	128 (52)	
Household's head characteristics					
Gender	Male	266 (82.1)	128 (48.5)	136 (51.5)	0.175
	Female	58 (17.9)	22 (38.6)	35 (61.4)	
Education level	Illiterate and primary	215 (67)	94 (43.7)	121 (56.3)	0.124
	High school and higher education	106 (33)	56 (52.8)	50 (47.2)	
Employment	Employed	188 (58.9)	104 (55)	85 (45)	0.001
	Unemployed/ housewife	132 (41.1)	46 (35.4)	84 (64.6)	
Married status	Married	258 (80.2)	123 (47.7)	135 (52.3)	0.492
	Other (Single / Divorced / Widowed)	63 (19.8)	27 (42.9)	36 (57.1)	
	Normal	162 (52.6)	78 (48.8)	82 (51.2)	
Weight status (based on BMI ⁶)	Wasted	50 (16.2)	18 (33.3)	36 (66.7)	0.096
	Overweight/ obese	96 (31.2)	46 (50.5)	45 (49.5)	
Waist circumference	Normal	236 (77.1)	107 (45.7)	127 (54.3)	0.759
	Abdominal obesity	70 (22.9)	33 (47.8)	36 (52.2)	

۳۴۰ ¹ Food Secure, ²Food Insecure, ³Rial is the currency of Iran, ⁴Mean Adequacy Ratio, ⁵Nutritional Functional Diversity,

۳۴۱ ⁶Body Mass Index. [†] Using Mann–Whitney U test, ^{††}Using Chi-squared test.

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۳۴۳ Table2. Association between NFD score of rural food and nutrition system with household's
 ۳۴۴ food security, Zahedan, Iran

Predictors	Household's food security status				
	Unadjusted		Adjusted†		
	FS ¹	FI ¹	FS	FI	
	OR (CI95%)		OR (CI95%)		
NFD of homestead production	Reference	1.047 (0.918-1.193)	Reference	1.123 (0.930-1.355)	
NFD of household's food processing	-	1.023 (0.916-1.143)	-	1.047 (0.899-1.219)	
NFD of Consumption	Food purchased from city	-	0.916 (0.880-0.955)***	-	0.928 (0.881-0.978)**
	Food purchased from village	-	1.045 (1.005-1.088)*	-	1.051 (1.000-1.104)*
	gift	-	1.061 (0.979-1.150)	-	1.057 (0.961-1.164)
	Native plants	-	1.311 (1.036-1.659)*	-	1.195 (0.890-1.604)
	Household's diet	-	0.952 (0.894-1.013)	-	0.969 (0.895-1.048)

¹Food Insecurity, *p<0.05, **p<0.01, ***p<0.001

†Adjusted for family size, income, household's under additional subsidy plan (Except for national subsidy), distance from city, sex and education of household's head, household's welfare index, employment of household's head

۳۴۶ Table 3. Association between NFD score of rural food and nutrition system with household's
 ۳۴۷ Mean Adequacy Ratio, Zahedan, Iran

		Household's MAR	
		Unadjusted	Adjusted†
Predictors		MAR ¹	MAR
		B (CI95%)	B (CI95%)
NFD of homestead production		-0.035 (-1.065-694)	0.412 (-0.450-1.275)
NFD of household's food processing		0.121 (-0.194-1.219)	0.419 (-0.297-1.134)
		0.233 (0.273-	
	Food purchased from city	0.756)***	0.353 (0.108-0.599)**
	Food purchased from village	0.032 (-0.192-0.332)	-0.017 (-0.266-0.232)
NFD of Consumption	Received gift	0.146 (-0.036-1.007)	0.458 (-0.059-0.976).
	Native plants	0.127 (-0.100-2.733)	0.876 (-0.504-2.256)
		1.904 (1.539-	1.714 (1.328-
	household's dietary	2.270)***	2.100)***

¹Mean Adequacy Ratio, *p<0.05, **p<0.01, ***p<0.001

†Adjusted for family size, age of household's head, household's income, household's under additional subsidy plan (Except for national subsidy), education of household's head, household's welfare index, employment of household's head

۳۴۸ Table4. Association between NFD score of rural food and nutrition system with BMI of
 ۳۴۹ household's head

		BMI ¹ of household's head					
		Unadjusted			Adjusted†		
Predictors			Overweight/ob			Overweight/ob	
	Normal	Wasting	esity	Normal	Wasting	esity	

		OR (CI95%)	OR (CI95%)		OR (CI95%)	OR (CI95%)
NFD of homestead production	Reference	0.955 (0.788-1.158)	1.035 (0.883-1.213)	Reference	0.947 (0.739-1.212)	0.977 (0.803-1.189)
NFD of household's food processing	-	0.900 (0.764-1.061)	0.941 (0.823-1.074)	-	0.874 (0.722-1.059)	0.966 (0.818-1.140)
NFD of Consumption	Food purchased from city	0.959 (0.912-1.009)	1.054 (1.007-1.103)	-	0.961 (0.902-1.023)	1.033 (0.983-1.085)
	Food purchased from village	0.990 (0.939-1.044)	0.978 (0.934-1.023)	-	1.023 (0.961-1.090)	0.981 (0.934-1.031)
	gift	1.025 (0.926-1.134)	1.034 (0.945-1.130)	-	1.005 (0.894-1.130)	1.047 (0.943-1.162)
	Native plants	0.854 (0.611-1.195)	1.016 (0.801-1.289)	-	0.949 (0.646-1.396)	0.966 (0.737-1.267)
	Household's diet	0.942 (0.860-1.033)	1.064 (0.991-1.142)	-	0.988 (0.892-1.116)	1.026 (0.946-1.113)

¹Body Mass Index, *p<0.05, **p<0.01, ***p<0.001

†Adjusted for family size, age of household's head, household's income, household's under additional subsidy plan (Except for national subsidy), residence status, education of household's head, household's welfare index, employment of household's head

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၃၀၁ Table 5. Association between NFD score of rural food and nutrition system with waist

၃၀၂ circumference of household's head

Predictors	Waist circumference of household's head	
	Unadjusted	Adjusted†

		Normal	Abdominal obesity	Normal	Abdominal obesity
		OR (CI95%)		OR (CI95%)	
		Reference		Reference	
NFD of homestead production		Reference	0.988 (0.843-1.158)	Reference	0.914 (0.751-1.112)
NFD of household's food processing		-	0.987 (0.863-1.129)	-	0.973 (0.828-1.144)
NFD of Consumption	Food purchased from city	-	1.058 (1.010-1.108)*	-	1.032 (0.979-1.088)
	Food purchased from village	-	0.975 (0.928-1.024)	-	0.974 (0.924-1.027)
	Gift	-	1.032 (0.945-1.126)	-	1.041 (0.934-1.161)
	Native plants	-	1.089 (0.850-1.394)	-	0.987 (0.749-1.300)
	Household's diet	-	1.041 (0.968-1.119)	-	0.982 (0.897-1.075)

*p<0.05, **p<0.01, ***p<0.001

†Adjusted for family size, age and sex of household's head, household's income, household's under additional subsidy plan (Except for national subsidy), household's welfare index, married status of household's head

۳۵۳ Discussion

۳۵۴ The results of the present study show that in rural food and nutrition system, the food purchased
 ۳۵۵ from city play the main role in the household's NFD score. In other words, it was shown that
 ۳۵۶ rural households highly rely on Zahedan city for household's dietary diversity. Additionally,
 ۳۵۷ NFD score of food purchased from the city was lower in food insecure household's whose
 ۳۵۸ distance was farther from the city compared to food secure households. Similar findings from a
 ۳۵۹ study performed in rural areas of Malawi showed that purchased foods more contribute to
 ۳۶۰ household nutritional diversity than home produced foods and household's living farther from
 ۳۶۱ roads and population centers had lower overall diversity [20]. It was reported that smallholder
 ۳۶۲ farming household's of Malawi, often purchased more than half of the foods consumed from the
 ۳۶۳ market [19].

374 Data on NFD score and the relationship between farm production diversity and diet diversity are
375 scarce [21, 22, 51, 52]. As well, no data are available on NFD on the continuum of a food system
376 or the association among the NFD score at different food sub-systems and nutrient adequacy and
377 household food security. Moreover, results of a meta-analysis showed that the effects of
378 production diversity on dietary diversity and nutrition in smallholder farm households are
379 positive, but small [53]. This finding may be due to the role of markets in achieving diverse diets
380 [20, 54]. In our study, very few households were the owners of agricultural land and NFD score
381 of crop production was very small. In contrast, more than 40% of the households had homestead
382 production and processing; however, NFD score were low and no association was found between
383 NFD score of home production/ processing and the nutritional outcomes, i.e. household food
384 security status, MAR, and anthropometric indicators. Remans *et al.* in their study did not observe
385 a significant association among NFD of edible crops, household dietary diversity score, and
386 household food security in rural areas of Africa [21].
387 We found no study examining the relationship of NFD score of household's food purchases and
388 diet with food insecurity and adequacy of micronutrients. Food insecure households had lower
389 NFD score of foods purchased from city than the NFD score for those foods purchased from the
390 village and native plants consumption compared to food secure households. As well, the NFD
391 score of diet was low and a positive association was found between NFD score of household's
392 diet and their MAR. It seems, that the socio-economic factors, such as illiteracy and
393 unemployment of household's head, low level of household's welfare index, household size, and
394 village's distance from city have impacts on low NFD score, nutrient inadequacy, and food
395 insecurity. Lockett *et al.* in their research found that some factors such as each additional person

386 in a household, lack of a primary-school education, and household's heads older than 50 years
387 old increase the likelihood of household's falling into the lowest quintile of total NFD [20].

388 One of our intentions in assessing NFD score in rural food and nutrition system was identifying
389 the relative role(s) of homestead production, processing, markets, and diet in nutritional diversity
390 as well as investigating its effect on household nutrient adequacy and food security. Since NFD
391 scores of homestead production and processing in food secure and insecure household's were
392 found to be similar, the women empowerment program [54-56] can be considered as an effective
393 approach on both increasing diversity in household's and reducing food insecurity. As well, the
394 development of local food markets with more affordable prices can increase household access to
395 diverse foods [18, 24]. Finally, although the NFD score of native plants was low, it was indicated
396 that they can play an important role in household diet in certain seasons, especially in food
397 insecure households.

398 **Strengths and limitations**

399 One of the strengths of this study was that the food and nutrition system was seen at different
400 stages, while most studies performed in this field have only seen the relationship between
401 production diversities or diet diversity with nutritional consequences separately [22, 53].

402 Furthermore, examining the relationship between NFD score and various nutritional outcomes,
403 i.e. food security status, adequacy of micronutrients, and anthropometric indicators was another
404 important point of the current study, while previous studies have often examined one or two
405 nutritional outcomes.

406 However, the results of the present study should be interpreted with some cautions, and its
407 limitations also need to be considered. It should be noted that we were not able to assess some

٤٠٨ factors affecting the NFD score of home products, including soil and water quality, garden size,
٤٠٩ and environmental factors. Half of the surveyed villages had no access to piped water and their
٤١٠ sources of agricultural water were saline water wells. Therefore, improving water access for
٤١١ subsistence farms seems to be a more promising development strategy.

٤١٢ The NFD of purchased foods was calculated from the data by two non-consecutive 24h dietary
٤١٣ recalls, which did not include any seasonal difference. Analyzing the NFD in household's diets
٤١٤ and food sources in different seasons would require data collection at different seasons.

٤١٥ **Conclusion**

٤١٦ A holistic perspective to food security which encompasses food diversity in all aspects of food
٤١٧ and nutrition system is missing in Iran. NFD is a metric describing diversity in providing
٤١٨ nutrients from farm to markets and all the ways directed to the consumption level. This study
٤١٩ showed the foods purchased from the city play the main roles in rural household's NFD score.
٤٢٠ NFD score of homestead production and household's processing were found to be five times less
٤٢١ than those of foods purchased from cities. An inverse and strong association was found between
٤٢٢ NFD scores of foods purchased from city and MAR.

٤٢٣ More studies are required to clarify whether NFD score can better reflect diversity compared to
٤٢٤ other indicators of diversity. Besides, the cut-off points for NFD to rate diversity adequacy
٤٢٥ should be defined. Additionally, further studies are needed to gain a better understanding on the
٤٢٦ issue that what types of markets and market transformations have what kinds of nutritional
٤٢٧ outcomes in the rural area of developing countries. Overall, the NFD score seems to have a
٤٢٨ potential to be used as a policy tool, because it can help policy makers to identify gaps in the

429 local food and nutrition system and then to plan appropriate interventions, especially in low-
430 income communities.

431 **Abbreviations**

432 NFD: Nutritional Functional Diversity; MAR: Mean Adequacy Ratio; DRI: Dietary Reference
433 Intake; AMEs: Adult Male Equivalent units; NAR: Nutrient Adequacy Ratio; HFIAS: Household
434 Food Insecurity Access Scale; BMI: Body Mass Index; SE: Standard Error; OR: Odds Ratios; CI:
435 Confidence Intervals; SPSS: Statistical Package for the Social Sciences; UCT: Unconditional
436 Cash Transfer; FS: Food secure; FI: Food Insecure.

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441 **Authors' contributions**

442 MS, HEZ and NO designed the study, performed the study and analyses, and wrote the main
443 paper. SMT helped analyses and interpret the data. All authors read and approved the final
444 manuscript.

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446 None.

447 **Availability of data and materials**

448 The datasets used and/or analyzed during the current study are available from the authors on
449 reasonable request.

450 **Declarations**

٤٥١ **Ethics approval and consent to participate**

٤٥٢ The study was approved by the ethics committee of National Nutrition and Food Technology
٤٥٣ Research Institute, Shahid Beheshti University of Medical Sciences, Tehran, Iran (ID:
٤٥٤ “IR.SBMU.NNFTRI.1398.032”). The required data were collected through face-to-face
٤٥٥ interviews with mothers (assisted by their husbands), after signing an informed consent form. All
٤٥٦ protocols were carried out in accordance with relevant guidelines and regulations.

٤٥٧ **Consent for publication**

٤٥٨ Not applicable.

٤٥٩ **Competing interests**

٤٦٠ The authors declare that they have no competing interests.

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Figures

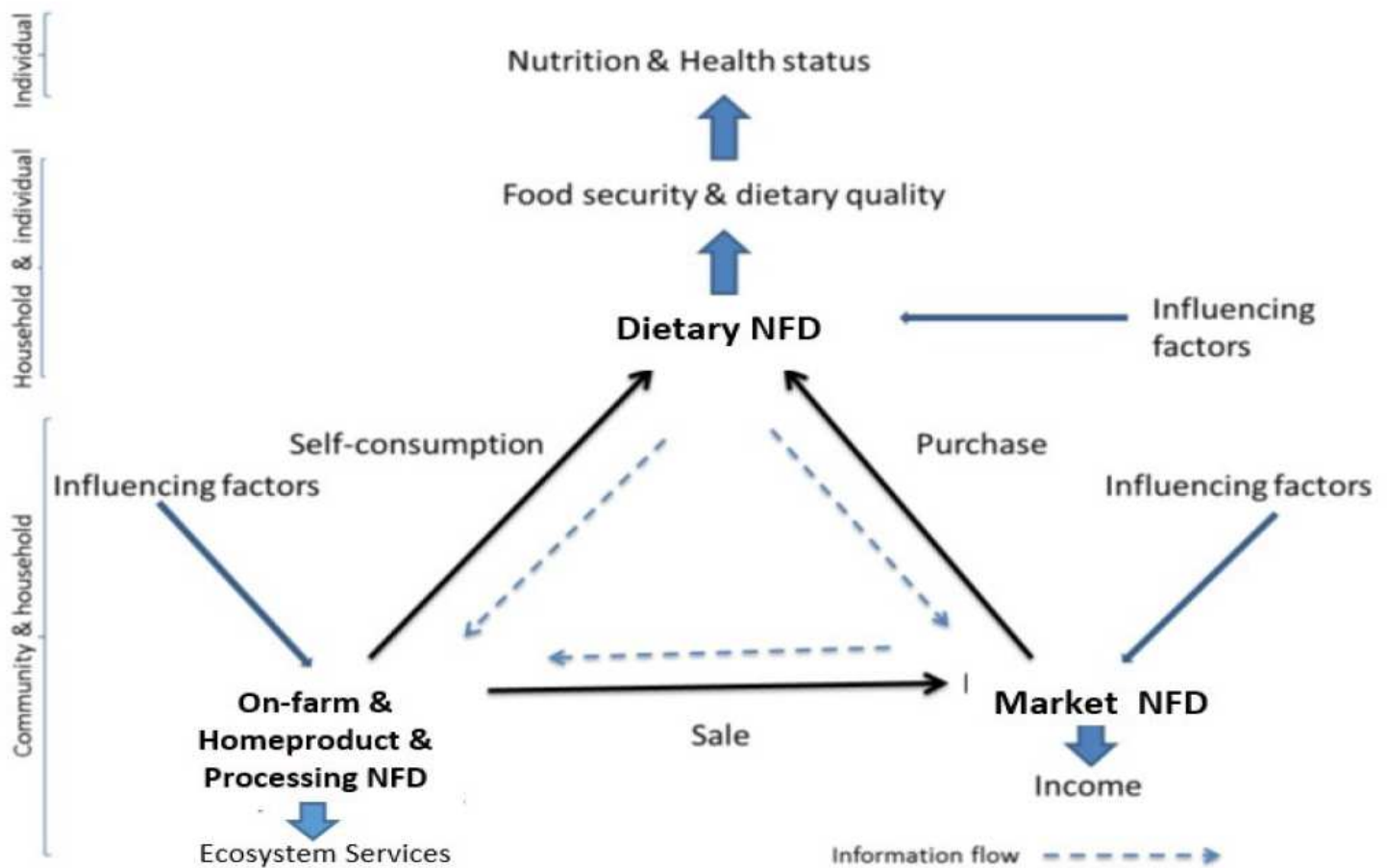


Figure 1

Conceptual framework on the linkage among the farm, homestead production and household's processing NFD, as well as the purchased food and dietary NFD in rural food and nutrition system [24]