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Food Sources and Lysine Intakes of Filipinos: Why Is It Important?

Imelda Angeles-Agdeppa[1,*], Frances Pola S. Arias[1,2], Marvin B. Toledo[1]

[1]Department of Science and Technology- Food and Nutrition Research Institute, NCR Philippines
[2]Department of Science and Technology- Science Education Institute, NCR Philippines
*Corresponding author: iangelesagdeppa@yahoo.com.ph

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Abstract Lysine is one of the essential amino acids for normal growth and development. However, it is the limiting amino acid in rice which is the staple food of Filipinos. The aim of this study is to evaluate the lysine intakes of selected Filipino populations and determine the vulnerable population groups that are at risk of having inadequacy of lysine intake by locale and wealth quintile. The data is obtained from the 2013 National Nutrition Survey with about 8,592 sample households (response rate: 87.7%) and 35,884 individuals used in the current analysis: 6-11 months old (n=355), 1-3 years old (n=1,450), 4-10 yo (n=6,909), 11-14 yo (n=4,060), 15-18 yo (n=3,204), and 19-49 yo (n=19,906). Food intake was collected on 2 non-consecutive days. The first food recall was collected from all household members. The second day recall was only from a random sub-sample of 50% of those members with a first day recall. Energy and nutrient content of foods were processed using an electronic Individual Dietary Evaluation System containing the updated Philippines Food Composition Table. Mean and usual lysine intake was estimated using the PC Software for Intake Distribution Estimation version 1.02. The mean intake of lysine of Filipinos is adequate across all physiologic age groups. However, the prevalence of lysine inadequacy was highest among 6 to 11 months old children (54%). For other agegroups, prevalence were 14% among 1-3 yo, about 2% among 4-10 yo; 8% among 11-14 yo; 13% among 15-18 yo, and 15% among 19-49 yo. Lysine inadequacy was also most common among females, the poorest sectors, and in the rural areas. Lysine intake of stunted children is lower than normal children. The result of this study is a step forward to design immediate interventions to address the marked inadequate lysine intake of the 6 to 11 months old infants.

Keywords: *lysine, amino acids, food sources, nutrient intake, physiological groups*

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1. Introduction

Protein is made up of amino acids which are the building blocks that build and repair worn-out tissues. There eight essential amino acids (EAAs) for human nutrition namely: phenylalanine (Phe), valine (Val), threonine (Thr), tryptophan (Trp), isoleucine (Ile), methionine (Met), leucine (Leu) and lysine (Lys). They are essential because they could not be synthesized by the body, hence, these must be obtained from diet. Insufficient intake of essential amino acids could adversely affect multiple metabolic pathways since they play diverse roles in human health [1]. Animal sources of protein contain all the essential amino acids, on the other hand, plant sources lack one or more-these are called the limiting amino acid [2]. Protein complementation is the most efficient way to get all amino acids into a vegetarian’s diet. Protein complementation is when you combine two vegetable proteins to get all amino acids that are essential for the body [3].

The biologically active form of lysine is L-lysine. Lysine as one of the essential amino acids plays an active role in the metabolism of protein, carbohydrates, and fatty acids. It builds muscle and rebuilds muscle after periods of illness and inactivity. Lysine is also necessary for normal growth and development because it increases the absorption of calcium and collagen formation which are important for muscle and bone health. Together with methionine, lysine forms carnitine which helps cells utilize fat as energy. Lysine also plays an important role in the immune system, including preventing recurrence of herpes simplex virus [4] and reducing morbidity as a result of diarrhea and bronchopneumonia [5]. Moreover, lysine supplementation can increase levels of C3, Ig G, Ig A, Ig M [6], and CD3 & CD4 [7]. These immunoglobulins are important part of the immune response to fight infections by specifically recognizing and binding to particular antigens, such as bacteria or viruses, and aiding in their destruction. CD3 and CD4 peroxidases, on the other hand, are co-receptors of the T cell receptor which assist the latter in communicating with antigen-presenting cells [8].

Determination of lysine requirement has gained attention because of its nutritional importance as the first limiting amino acid in cereals and rice. The amount of lysine in rice is not sufficient to sustain the body's needs.

Based on the FAO/WHO/UNU Expert Consultation on Protein and Amino acid requirements in Human Nutrition, lysine requirement of infants is higher as compared to adult requirements, and recent recommendations indicated a lysine requirement is highest among infants 6-11.9 months with about 64 mg/kg body weight /day [9]. Table 2 presents the requirements by age groups. Older populations have lower requirements. Most estimates of a limiting amino acid requirement, including lysine, have been made in Western well-nourished young male adults and their modulation by factors such as sex, dietary, and nutritional factors. Also, the possibility that the limiting amino acid requirements might differ among populations living in other environments is a concern [10]. Recent studies in Indian subjects showed that lysine requirement is not different between well-nourished young adults living in the United States and those in India. However, the same does not hold true for undernourished Indian adults whose lysine requirement is significantly higher (44 mg/kg/day) than that of healthy subjects (30 mg/kg/day). This higher requirement was attributed to intestinal parasite infestation [11].

Persons with inadequate lysine may experience fatigue, nausea, dizziness, loss of appetite, agitation, redness of the eyes, lethargic growth, anemia, and disorders of the reproductive system [12]. On the other hand, those with a high risk of lysine deficiency are the athletes, body builders, burn patients because of high demands; the vegetarians, and vegans because plants are poor sources of lysine. These people can get additional sources of L-lysine from nutritional supplements [12]. Food sources that are high in L-lysine include high protein foods like nuts, red meat, fish and seafood, eggs, milk, cheese, legumes, and sardines. While lysine in the diet is considered safe, excessive doses may cause gallstones. There were also reports of renal dysfunction, including Fanconi syndrome and renal failure. Thus, lysine supplements should still be taken with precaution [12].

Considering the important role of lysine in growth, and muscle and bone health, estimation of lysine intake of Filipinos is necessary to determine the vulnerable population groups that are at risk of having inadequacy of lysine intake by locale and wealth quintile for policy recommendation.

2. Methodology

2.1. Study Design and Population

This study used the data extracted from the 2013 National Nutrition Survey (NNS). The 2013 NNS is a cross-sectional study conducted nationwide in the Philippines. A multi-staged stratified sampling design was used to represent 17 regions encompassing 80 provinces, covering both urban and rural areas. The first stage of sampling is the selection of Primary Sampling Units, consisting of one barangay or a combination of contiguous barangays with at least 500 households each. From these PSUs, enumeration areas with 150 to 200 households were identified, from which housing units were randomly selected. The third stage was the random selection of the households, which is the ultimate sampling unit [13].

The Ethics Committee of Food Nutrition Research Institute (FNRI) approved the survey protocol. All surveyed households provided informed consent prior to participation.

A total of 8,592 sample households with 87.7% response rate were covered in the dietary survey. From the total population of individual respondents, those with data on dietary intake were grouped by age: 6-11 months old (n=355), 1-3 years old (n=1,450), 4-10 years old (n=6,909), 11-14 years old (n=4,060), 15-18 years old (n=3,204), and 19-49 years old (n=19,906), resulting in this study's analytics sample size of 35,884 individuals [13].

2.2. Data Collection

2.2.1. Dietary Information

Trained dietitians conducted face-to-face 24-h dietary recalls with a parent or caregiver of each child during household visits, wherein the dietitian recorded all food and beverages that the child consumed the previous day. A first 24-h recall was performed on all children and a second 24-h recall was repeated in 50% of randomly selected households, typically two days after the first recall. The amount of each food item or beverage was estimated while using common household measures, such as cups, tablespoons, by size, or number of pieces. The information was then converted to grams while using a portion-to-weight list for common foods compiled by FNRI or through weighing of the food samples [13].

2.2.2. Populating the Philippine FCT with Inclusion of Lysine

The current Food composition table (FCT) of the Philippines does not contain lysine. Hence, lysine values of all food items consumed were barrowed from other FCT. The updated FCT new food items (325) found in the 2013 food consumption survey. With this effort, the new Philippine FCT contains 27 nutrients with a total of 1359 food items from the original FCT with 12 nutrients and 1034 food items. About half of data (47%) were from the USDA National Nutrient Database and 39% data from the original Filipino FCT compiled by FNRI [14]. The rest of the data were sourced from food composition database of Association of Southeast Asian Nations and other Asian countries such as Japan (8%) and information from food labels (6%). All imported data were adapted according to the FAO INFOODS guidelines [15]. The amino acid content of foods was calculated after adjusting for protein content. The Protein Digestibility Corrected Amino Acid Score (PDCAAS) was used in the calculation of the amino acid as it is the method preferred for the routine prediction of the protein quality [9]. Stated below is the data compilation procedure for Philippine data of Lysine. Food records were entered and estimated energy and nutrient intakes were processed with a computer system called Individual Dietary Evaluation System (IDES). This system contains the data of the updated Filipino Food Composition Tables (FCT) created for this study.

Data Compilation Procedure:

1. Followed the Food Matching Guidelines of INFOODS version 1.2 which include the following criteria:

a. For food identification:
- food name and descriptors;
- taxonomic/ scientific name; and
- water and fat content

b. For food components:
- expression;
- definition;
- analytical methods;
- unit; and
- denominator

2. Adapt to protein contents between foods since amino acid content in foods depend on protein content

3. Adjust lysine data with values for digestibility of protein in humans

Formulas 1-3 were used to compute for the adjusted lysine contents of existing food items in the FCT and new food items included in the 2013 NNS. On the other hand, Table 1 presents the values for true digestibility of protein food sources.

Formula 1. Lysine content from Food Match

Lysine content= Protein content of food (g) x Lysine content of food match

Formula 2. Adjusted Lysine value

Adjusted Lysine value= (Lysine value per 1 g of Protein) x True Digestibility

Formula 3. Adjusted Lysine value with moisture content

A. Existing FCT food items:

Adjusted lysine value $_{mc}$ = 100- Moisture content (FCT) X Lysine value

B. New FCT food items:

Adjusted lysine value $_{mc}$ = 100- Moisture content from Food Match.

The Lysine requirements from the 2007 WHO/FAO/UNU Expert Consultation on the "Protein and Amino Acid Requirements in Human Nutrition" [16] was considered as the EAR for lysine which will be used to assess adequacy of lysine intake of the different age groups.

Table 1. Values for the Digestibility of Protein in Humans

Protein Source	True Digestibility (%)	Protein Source	True Digestibility (%)
American mixed diet	96	Oatmeal	86
Beans	78	Oats, cereal	72
Brazilian mixed diet	78	Peanut butter	95
Chinese mixed diet	96	Peanuts	94
Corn, cereal	70	Peas, mature	88
Corn, whole	87	Rice, cereal	75
Cottonseed	90	Rice, polished	88
Egg	97	Soy flour	86
Farina	99	Soy protein isolate	95
Filipino mixed diet	88	Sunflower seed flour	90
Indian rice + beans diet	78	Triticale	90
Indian rice diet	77	Wheat flour, white	96
Indian rice diet + milk	87	Wheat, gluten	99
Maize	85	Wheat, cereal	77
Maize + beans	78	Wheat, refined	96
Maize + beans + milk	84	Wheat, whole	86
Meat, fish	94		
Milk, cheese	95		
Millet	79		

Source [9].

Table 2. Lysine Requirement per Age Group

Age group	Lysine requirement (mg/kg body weight/day)	Lysine requirement + 20% (mg/kg BW/ day)[a]
6 months old (6-11.9 mo)	64	77
1-2 years old(12-35.9 mo)	45	54
3-10 years old	35	42
11-14 years old	35	42
15-18 years old	33	40
>18 years old	30	36

[a]added requirement for infections e.g. parasitic infestation
Source [16].

Socio-demographic variables, extracted from the main database of the survey were: ID code, age, survey weights, recorded day, sex, urbanity or locale. The variables collected for the household information were the following: type of dwelling unit, tenure status of the house, tenure status of the lot, type of roof, type of wall, type of floor, number of bedrooms, type of fuel used, and transport utilities. Wealth index was computed based on principal component analysis (PCA) of household assets, household characteristics, access to utilities, and infrastructure variables. Weights or factor were generated for each household asset/information through PCA. The standardized scores were then used to create the break points that define the wealth quintiles: poorest, poor, middle, rich, and richest.

2.2.3. Food Groups

To investigate food sources of lysine, a list of 85 food groups was created in a similar format from previous dietary intake studies [14]. All foods and beverages reported were assigned to one of the 85 food groups. Fortified milk powder manufactured for toddlers and young children in the Philippines is called toddler/preschooler milk in this study while other milk was the regular powdered/fluid milk. The weighted percentage contribution of each food group for selected key nutrients was calculated by adding the amount of a given nutrient provided by each food group for all individuals and dividing by the total intake of that nutrient consumed by all individuals from all foods and beverages.

2.3. Statistical Analysis

Mean ± SE usual intakes, percentile distributions, and prevalence of inadequate intakes of lysine were assessed using the Iowa State University (ISU) method. The ISU uses a statistical adjustment procedure that better explains some of the characteristics of dietary intake data [14]. Briefly, the ISU method estimates distributions of usual nutrient intake by eliminating the effect of the day-to-day variability in consumptions from daily intakes. It uses data provided by≥2 independent 24hour food recall. A good feature of the method is that it permits incorporation of the study design to generate national representative results [15]. All calculations were carried out using sampling weights to adjust the complex design of the survey.

For the evaluation of lysine intakes, implausible intakes were defined as those that exceed 1.5 times the 99th percentile of the observed intake distribution in the corresponding age group. Intakes above this upper limit were substituted by a random value generated from a uniform distribution in the interval with lower bound equal to the 95th percentile of observed intake and an upper bound equal to 1.5 times the 99th percentile. The prevalence of inadequacy in a group is estimated as the proportion of individuals with usual lysine intakes below the Estimated Average Requirement (EAR) i.e. EAR-cut-point method. The Lysine requirements from the 2007 WHO/FAO/UNU Expert Consultation was considered as the EAR for lysine which was used to assess adequacy of lysine intake of the different age groups with additional 20% of the each requirement for the effect of infections during absorption e.g. parasitic infestation.

3. Results

3.1. General Profile of Respondents

Table 3 shows the general profile of the respondents according to age groups. Most of the respondents were male among the age groups 1-3 years old (52.1%), 4-10 years (50.5%), 11-14 years (52.3%), 15-18years (53.3%), 19-49 years (50.5%). On the other hand, most respondents were female among the 6-11 months old children (50.8%).

Most of the respondents across all the age groups were from rural areas and from the poorest wealth quintile. In terms of work status among adults, 57.86% of the 19-49 years old age group is working. However, within the younger age groups, some of the 15-18 years old (11.72%) already work for a living. The prevalence of stunting among the different age were 13.83% among 6-11 months old, 30.15% 1-3 years old children, 29.83% among 4-10 years old, 30.79% among 11-14 years old, 31.02% among 15-18 years old, and 30% among 19-49 years old.

3.2. Lysine Intake of 6-11 Months Infants

Table 4 shows the mean lysine intake among 6-11 months infants was 105.9 mg/kg BW/d. There was no difference in intake between sexes. However, lysine intake was significantly lower in rural areas and in the poorest quintile. The prevalence of lysine inadequacy among infants aged 6 to 11 months was 54%; the prevalence was higher in rural areas (64%) than in urban areas (46%). Comparing the data across wealth index, the poorest (67%) and the poor (64%) wealth quintiles have the highest prevalence of inadequacy than those in the other wealth indexes. Stunted and normal infants have equal mean lysine intake.

3.3. Lysine Intake of 1-3 Years Old Children

Among the young children aged 1-3 years old, the mean lysine intake was 145.2 mg/kg BW/d. (Table 5). There was no difference in lysine intakes between male and female. Lysine intake was significantly lower in rural areas (121 mg/kg BW/d) than in urban areas (165.8mg/kg BW/d). The poorest quintile had the lowest intake across the wealth index. The prevalence of lysine inadequacy among young children was 14%. The inadequacy of intake was higher in rural areas (18%) than in urban areas (10%). There is a declining prevalence of inadequacy as wealth quintile is improved. The poorest and poor wealth quintiles were 25% and 15%, respectively. Lower prevalence was observed in other wealth quintiles. Stunted children have lower mean lysine intake compared to normal children.

3.4. Lysine Intake of 4-10 Years Old Children

Among the 4 -10 year old children, the mean lysine intake was 106.3 mg/kg BW/d (Table 6). However, lysine intake was significantly lower among females (104.5mg/kg BW/d) than males (108.1 mg/kg BW/d). Comparing between localities, those residing in the urban area have significantly higher mean lysine intake (114.6mg/kg BW/d) than those in rural area (97.7 mg/kg BW/d). The prevalence of lysine inadequacy among this age group is at 2%.

Table 3. General Profile of the Respondents

	Age Group					
	6-11 mos	**1-3 yo**	**4-10 yo**	**11-14 yo**	**15-18 yo**	**19-49 yo**
Characteristics	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Sex						
Male	174 (49.15)	768 (52.1)	3544 (50.53)	2152 (52.3)	1755 (53.29)	10,456 (50.47)
Female	180 (50.85)	706 (47.9)	3469 (49.47)	1963 (47.7)	1538 (46.71)	10,262 (49.53)
Urbanity						
Rural	189 (53.39)	798 (54.14)	4036 (57.55)	2439 (59.27)	1832 (55.63)	11362 (54.84)
Urban	165 (46.61)	676 (45.86)	2977 (42.45)	1676 (40.73)	1461 (44.37)	9356 (45.16)
Wealth Quintile						
Poorest	86 (24.86)	411 (28.64)	2056 (30.14)	1166 (29.14)	737 (22.95)	4097 (20.29)
Poor	84 (24.28)	288 (20.07)	1516 (22.23)	944 (23.59)	732 (22.8)	4284 (21.22)
Middle	71 (20.52)	296 (20.63)	1278 (18.74)	735 (18.37)	680 (21.18)	4132 (20.47)
Rich	56 (16.18)	247 (17.21)	1063 (15.58)	637 (15.92)	562 (17.5)	3904 (19.34)
Richest	49 (14.16)	193 (13.45)	908 (13.31)	520 (12.99)	500 (15.57)	3771 (18.68)
Educational Level *(15 yo and above)*						
No grade completed/Kinder/Prep	-	-	-	-	34 (1.03)	580 (2.81)
Elementary Level	-	-	-	-	533 (16.22)	7002 (33.94)
High School Level	-	-	-	-	2265 (68.91)	7376 (35.75)
College Level	-	-	-	-	40 (1.22)	1134 (5.5)
Vocational Level	-	-	-	-	415 (12.63)	4541 (22.01)
Work Status*(15 yo and above)*						
No Occupation	-	-	-	-	2907 (88.28)	8730 (42.14)
Has Work	-	-	-	-	386 (11.72)	11988 (57.86)
Prevalence of Stunting						
Normal	299 (86.17)	1003 (69.85)	4838 (70.17)	2803 (69.21)	2206 (68.98)	35 (70)
Stunted	48 (13.83)	433 (30.15)	2057 (29.83)	1247 (30.79)	992 (31.02)	15 (30)

Table 4. Distribution of Lysine Intakes of 6-11 mos. old Children by Sex, Urbanity and Wealth Quintile: Philippines, 2013

6-11months	**n**	**Lysine Requirement (mg/kg/d)[a]**	**Mean and Percentiles**								**Prevalence of inadequacy (%)**
			P5	***P10***	***P25***	***Median***	**Mean ± SE**	***P75***	***P90***	***P95***	
All	355	77	4	7	18	64	105.9 ± 6.3	158	253	340	54
Sex											
Male	174	77	5	7	22	82	116.7 ± 9.1	171	275	356	48
Female	181	77	4	6	15	50	95.6 ± 8.9 [NS]	138	243	320	60
Urbanity											
Rural	192	77	4	6	14	42	82.5 ± 7.3	117	214	284	64
Urban	163	77	5	7	24	90	125.8 ± 10.3*	182	292	381	46
Wealth											
Poorest	87	77	3	4	10	35	83.1 ± 12.6	109	230	322	67
Poor	85	77	4	7	14	42	86.8 ± 13.1*	116	217	304	64
Middle	71	77	5	8	19	61	116.6 ± 16.2*	167	314	314	56
Rich	56	77	6	8	21	74	110.4 ± 12.3*	188	289	321	46
Richest	47	77	10	18	63	136	149.3 ± 16.3*	204	295	354	28
Height-for- age											
Stunted	52	77	4	8	21	58	127.4 ± 29.5	146	311	476	58
Normal	303	77	4	7	16	63	103.3 ± 6.4 [NS]	162	253	311	55

[a] 2007 WHO/FAO/UNU Expert Consultation lysine requirements+ 20% added requirements for infections
*Significantly different; Independent T-test
**Significantly different; Anova
NS - Not Significant

Table 5. Distribution of Lysine Intakes of 1-3 years old Children According to Sex, Urbanity and Wealth Quintile (mg/kg/d): Philippines, 2013

1-3 years old	n	Lysine Requirement (mg/kg/d)[a]	Mean and Percentiles								Prevalence of inadequacy (%)
			P5	P10	P25	Median	Mean ± SE	P75	P90	P95	
All	1450	54	32	46	77	126	145.2 ± 2.5	191	267	324	14
Sex											
Male	756	54	35	49	80	126	145.2 ± 3.4	188	264	321	12
Female	694	54	30	43	74	124	145 ± 3.7[NS]	193	274	333	15
Urbanity											
Rural	789	54	28	39	65	105	121 ± 2.8	159	224	270	18
Urban	661	54	39	55	91	146	165.8 ± 4.1*	216	299	362	10
Wealth											
Poorest	404	54	24	33	54	86	101.1 ± 3.3	133	188	229	25
Poor	284	54	32	44	71	114	132.4 ± 5**	174	244	294	15
Middle	292	54	35	49	79	125	141.6 ± 5**	186	256	305	12
Rich	245	54	48	66	105	162	183.3 ± 7**	238	327	391	6
Richest	187	54	58	76	116	172	187.3 ± 7.1**	242	318	370	4
Height-for-age											
Stunted	433	54	36	48	76	117	131.7 ± 3.7	172	234	278	13
Normal	1004	54	31	45	78	130	150.8 ± 3.2*	198	279	342	14

[a] 2007 WHO/FAO/UNU Expert Consultation lysine requirements+ 20% added requirements for infections
*Significantly different; Independent T-test
**Significantly different; Anova
NS- Not Significant.

Table 6. Distribution of Lysine Intakes of 4-10 years old Children According to Sex, Urbanity and Wealth Quintile (mg/kg/d): Philippines, 2013

4-10 years old	N	Lysine Requirement (mg/kg/d)[a]	Mean and Percentiles								Prevalence of inadequacy (%)
			P5	P10	P25	Median	Mean ± SE	P75	P90	P95	
All	6909	42	49	58	75	99	106.3 ± 0.5	130	164	188	2
Sex											
Male	3485	42	59	77	101	132	108.1 ± 0.7	166	190	2	2
Female	3424	42	57	74	97	127	104.5 ± 0.7*	161	185	3	3
Urbanity											
Rural	3990	42	51	67	90	120	97.7 ± 0.7	154	178	5	5
Urban	2919	42	67	85	108	138	114.6 ± 0.8*	170	192	1	1
Wealth											
Poorest	2024	42	48	62	82	108	88.2 ± 0.8	136	155	6	6
Poor	1504	42	53	70	92	121	99.8 ± 1.1**	155	181	4	4
Middle	1267	42	65	80	101	126	105.9 ± 1**	153	172	1	1
Rich	1037	42	70	87	112	143	119.6 ± 1.4**	179	206	1	1
Richest	888	42	75	94	121	154	128 ± 1.6**	190	214	<1	<1
Height-for-age											
Stunted	2056	42	44	53	71	98	106.7 ± 1.1	132	172	200	4
Normal	4840	42	51	60	77	100	106.1 ± 0.6[NS]	128	161	183	2

[a] 2007 WHO/FAO/UNU Expert Consultation lysine requirements+ 20% added requirements for infections
*Significantly different; Independent T-test
**Significantly different; Anova
NS- Not Significant.

3.5. Lysine Intake of 11-14 Years Old Children

Table 7 shows that the average lysine intake of 11-14 years old children was 74.6 mg/kg/d. Lysine intake was significantly lower in rural areas (69.7 mg/kg/d) and in the poorest quintile (62.3 mg/kg/d). Females had lower intake compared to male children. The prevalence of lysine inadequacy among 11-14 years old children was 8%.

3.6. Lysine Intake of 15-18 Years Old Adolescents

For adolescents 15-18 years old, the average lysine intake was 64.3 mg/kg/d. (Table 8). Lysine intake was significantly lower in rural areas (59.3 mg/kg/d) and poorest quintile (53.8 mg/kg/d). Males had higher intake compared to females. The prevalence of lysine inadequacy among adolescents was 13%.

Table 7. Distribution of Lysine Intakes of 11-14 Years Old Adolescents According to Sex, Urbanity and Wealth Quintile (mg/kg/d): Philippines, 2013

11-14 years old	n	Lysine Requirement (mg/kg/d)[a]	Mean and Percentiles								Prevalence of inadequacy (%)
			P5	P10	P25	Median	Mean± SE	P75	P90	P95	
All	4060	42	38	44	55	71	74.6 ± 0.4	89	110	125	8
Sex											
Male	2119	42	43	49	60	75	78.7 ± 0.6	93	113	127	5
Female	1941	42	34	40	51	66	70.3 ± 0.6*	85	106	120	13
Urbanity											
Rural	2412	42	34	40	51	66	69.7 ± 0.5	84	105	118	12
Urban	1648	42	43	49	61	76	79.5 ± 0.6*	94	114	128	4
Wealth											
Poorest	1145	42	29	34	44	58	62.3 ± 0.7	76	95	108	21
Poor	935	42	36	42	53	67	71.8 ± 0.9**	86	107	123	10
Middle	730	42	40	46	56	71	73.6 ± 0.9**	88	105	117	6
Rich	631	42	51	57	69	83	86.4 ± 1**	101	119	132	1
Richest	510	42	52	58	69	82	84.9 ± 1**	98	115	126	1
Height-for-age											
Stunted	1250	42	38	44	56	73	77.3 ± 0.8	94	116	131	8
Normal	2808	42	38	44	55	70	73.4 ± 0.5*	88	107	121	8

[a] 2007 WHO/FAO/UNU Expert Consultation lysine requirements+ 20% added requirements for infections
*Significantly different; Independent T-test
**Significantly different; Anova ; NS- Not Significant.

Table 8. Distribution of Lysine Intakes of 15-18 years old Adolescents According to Sex, Urbanity and Wealth Quintile (mg/kg/d): Philippines, 2013

15-18 yrs old	n	Lysine Requirement (mg/kg/d)[a]	Mean and Percentiles								Prevalence of inadequacy (%)
			P5	P10	P25	Median	Mean	P75	P90	P95	
All	3204	40	32	37	47	61	64.3 ± 0.4	77	96	109	13
Sex											
Male	1701	40	34	40	50	63	66.8 ± 0.6	80	98	111	10
Female	1503	40	30	35	45	58	61.6 ± 0.6*	75	93	105	16
Urbanity											
Rural	1789	40	28	33	42	55	59.3 ± 0.6	72	91	104	20
Urban	1415	40	37	43	53	66	68.7 ± 0.6*	81	98	110	7
Wealth											
Poorest	717	40	25	29	38	50	53.8 ± 0.8	66	83	95	28
Poor	711	40	29	34	43	56	59.5 ± 0.8**	72	89	101	18
Middle	660	40	33	39	48	61	64.6 ± 0.9**	77	95	107	11
Rich	548	40	39	44	54	66	68.3 ± 0.9**	80	95	106	5
Richest	488	40	44	50	60	72	75.1 ± 1**	87	103	115	2
Height-for-age											
Stunted	993	40	31	36	47	61	65.8 ± 0.8	80	100	116	14
Normal	2207	40	32	37	47	61	63.6 ± 0.5[NS]	77	94	105	13

[a] 2007 WHO/FAO/UNU Expert Consultation lysine requirements+ 20% added requirements for infections
*Significantly different; Independent T-test
**Significantly different; Anova

3.7. Lysine Intake of 19-49 Years Old Adults

Table 9 shows that the mean lysine intake among adults was 57.5 mg/kg/d. Lysine intake was significantly lower in rural areas (54.9 mg/kg/d) and poorest quintile (51.1 mg/kg/d). Males had higher lysine intake compared to females. The prevalence of lysine inadequacy among adults was 15%. The prevalence of inadequacy of lysine intake decreases as wealth quintile increases.

Table 9. Distribution of Lysine Intakes of 19-49 years old Adults According to Sex, Urbanity and Wealth Quintile (mg/kg/d): Philippines, 2013

19-49 years old	N	Lysine Requirement (mg/kg/d)[a]	Mean and Percentiles								Prevalence of inadequacy (%)
			P5	P10	P25	Median	Mean	P75	P90	P95	
All	19906	36	28	33	42	54	57.5 ± 0.2	69	86	98	15
Sex											
Male	9958	36	31	36	49	59	62.4 ± 0.3	75	93	105	9
Female	9948	36	26	30	39	50	52.6± 0.3*	63	78	89	19
Urbanity											
Rural	10956	36	26	31	39	51	54.9 ± 0.3	66	84	96	19
Urban	8950	36	30	35	44	57	59.8± 0.4*	72	88	100	11
Wealth											
Poorest	3930	36	23	27	36	47	51.1± 0.9	63	80	92	26
Poor	4125	36	26	30	39	50	53.4± 0.7**	64	80	91	19
Middle	4012	36	29	33	42	54	57.6± 0.7**	69	86	98	14
Rich	3736	36	33	38	47	58	61.2± 0.8**	73	88	99	8
Richest	3594	36	32	37	47	59	62.2± 0.8**	74	91	104	8

[a] 2007 WHO/FAO/UNU Expert Consultation lysine requirements+ 20% added requirements for infections
*Significantly different; Independent T-test
**Significantly different; Anova
NS- Not Significant.

3.8. Food Sources of Lysine

Almost half (43%) of the total lysine intake was from infant formula for 6-11 months babies. The other top 4 sources of lysine for 6 11 months babies were other milk (powdered and fluid), rice, growing up formula milk, and infant cereals. Other milk (25%) and growing-up formula milk (17%) were the top 1 and 2 food sources of lysine for children age 1-3 years old followed by fish and shellfish, rice, and poultry. For 4-10 years old children, fish and shellfish was the top 1 food sources of their lysine intake while rice was the second contributor with 20% contribution to the total lysine intake. About 20% were from poultry and pork and only 7% was from other milk (Figure 1).

Fish and shellfish, rice, pork, and poultry were the common top four (4) food sources for all age group. Sausages/hotdogs, luncheon meat and cold cuts were the top 5 source of lysine for 11-14 years old and 15-18 years old while eggs and dishes with eggs for 19 years old and above (Figure 2).

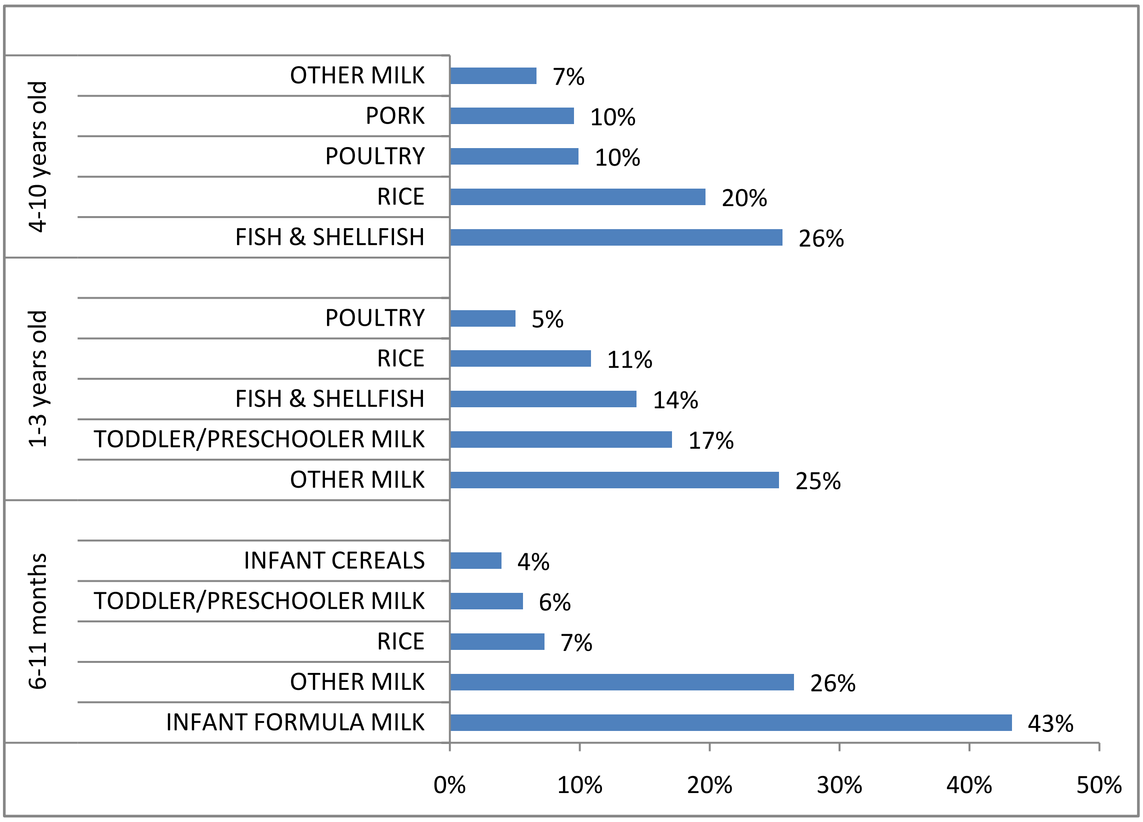

Figure 1. Top 5 food sources of total lysine intake among 6-11 months, 1-3 years old and 4-10 years old

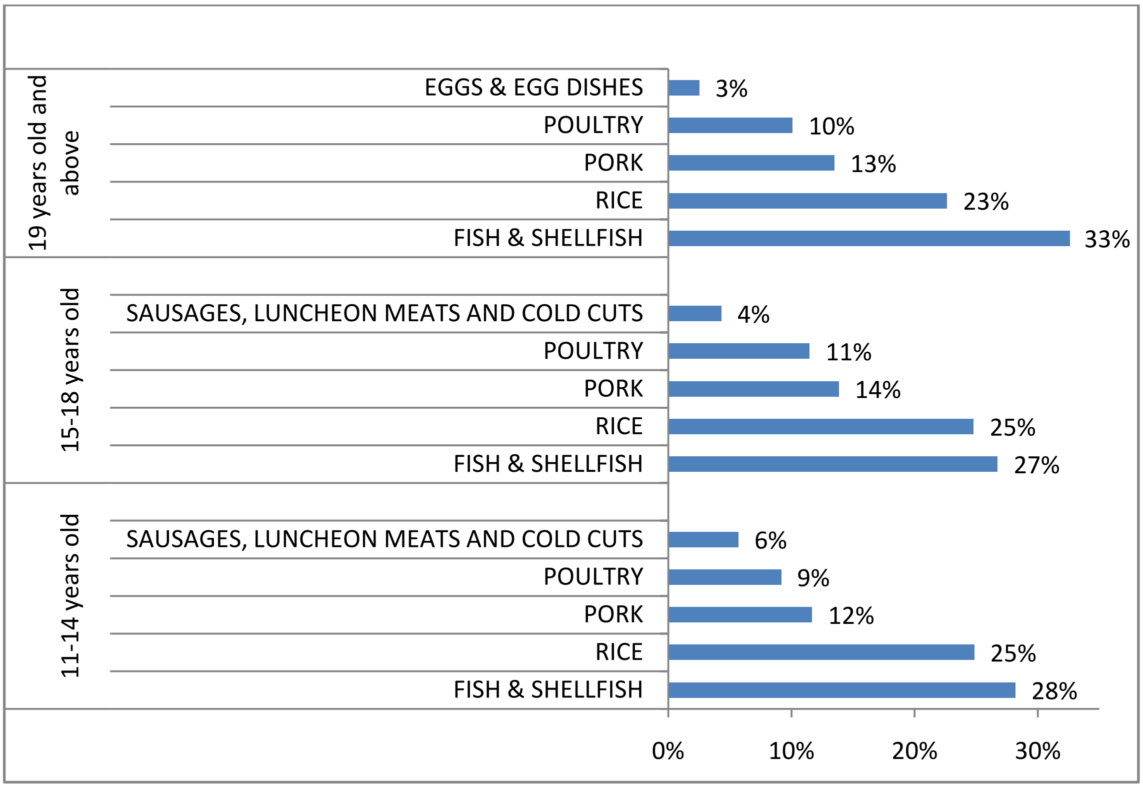

Figure 2. Top 5 food sources of total lysine intake among 11-14 years old, 15-18 years old and 19 years old and above

4. Discussion

This study evaluated the lysine intakes of selected Filipino population by age groups, locale and wealth quintile. Lysine inadequacy exists in all agegroups in this study but the prevalence is significantly highest among infants 6-11 months old as compared with the other agegroups. The high prevalence might be due to the poor complementary feeding during this age. The top 5 sources of lysine for 6-11 months infants were infant formula (43%), other milk (26%), rice (7%), toddler/preschool milk (6%), and infant cereals (4%). A recent analysis of nutrient intake and food sources of infants revealed that considerable high prevalence of inadequate intakes were found for protein (43%), and other B- vitamins including vitamins vitamin A (84%), iron (76%) and zinc (63%) [17]. On the other hand, the top-5 most consumed food items were fried rice, human milk, infant formula, cookies and cow’s milk. This lack of variety in the diet might have been a factor affecting the prevalence of stunting observed in this study (13.8%). Stunted children in this agegroup had 58% inadequacy of lysine intake. Incorporating high-quality protein source into the diet of the children has shown to have a positive impact on the improvement of nutritional status. Since lysine is the limiting amino acid in rice, the results of this study are important to emphasize the need to develop nutritious complementary foods that will fill the nutrient gap in this agegroup coupled by intensive nutrition education among parents to prevent stunted growth.

Lysine, along with other amino acids such as threonine and methionine, has been associated with the release of growth hormone in young children. Thus, the dietary restriction of these essential amino acids affects the production of plasma insulin-like growth factor. In a study determining the role of protein and amino acids on child growth, protein deficiency was identified to be the principal dietary cause of growth failure in children. Hence, protein quality was a potential determinant of nutritional status and growth in children [18]. The inadequacy level among the other agegroups is also a cause of concern because amino acids are involved in building muscles and repairing worn – out tissues.

Human growth is regulated by the mechanistic target of rapamycin complex C1 (mTORC1), a pathway that is mediated by the availability of amino acids. This might explain the results of this study that stunted children had lower intake of lysine than their normal peers [19]. This is manifested also in the results of the National Nutrition Survey (NNS) of the Department of Science and Technology – Food and Nutrition Research Institute wherein the prevalence of stunting was 30.1% [13]. However, the amino acid requirements of young children—particularly those at high risk like stunting are not yet established. Advances in metabolomics and mass spectrometry facilitate the rapid quantification of serum metabolites including amino acids, thus, it is timely to investigate their role in the pathogenesis of stunting and its metabolites. Since the negative impact of protein malnutrition on growth was deemphasized in favor of addressing micronutrient deficiencies, elucidating the mechanistic pathways that lead to stunting through application of advances in modern technology is critical for its prevention to improve immediate and long-term health among children [19].

The place of residence demonstrated that the mean lysine intakes of individuals residing in urban areas are higher as compared to those in rural areas. Although fish and shellfish are the major sources of lysine in the older agegroups aged >4 years old, only 26 to 33 % were consuming. These findings are supported by the data in the 2013 NNS where 16.7 % of Filipino households were severely food insecure and was higher in rural (20%) than in urban areas (13.5%). Similar to these results, intra-country variations in Pakistan were observed and showed significant differences from the country average. The cities and surrounding areas have lower food energy availability than the rural areas. Also, total protein and animal protein consumption were often greater in the urban and city areas [20]. Animal protein are much more bioavailable as compared to the plant sources of protein. A study conducted in rural Bangladesh on amino acid intakes also highlighted that protein intake were lower in rural areas. Based on a 1996 report by the United Nations Subcommittee on Nutrition, it was found out that Bangladeshis have low intake of lysine, and overall, lower intakes of amino acids even compared to other developing countries [21].

Further analysis also indicates that there is a significant difference between the lysine intake of the rich and the poor. The diets of individuals within the poor wealth quintile are heavily based on cereals. Such diets are likely to be low in a number of micronutrients, including lysine. A study on the food and nutrient intakes of Filipino adults revealed that Filipinos in the poor wealth quintile had higher energy and nutrient inadequacies and the major source of different nutrients is rice wherein lysine is the limiting amino acid. Similarly, food availability data from various countries demonstrated that as wealth decreases, major changes in food patterns were also observed, particularly in the decrease of the consumption of animal protein foods while there is increase in dependency on cereals. This means that lysine intake parallel the changes in food and energy protein [20]. It was also found, of the essential amino acids, lysine is the amino acid for which the largest differences occur between the diets of the rich and the poor. Lysine content of most cereals ranges from 26 to 38 mg per gram of protein whereas the lysine content of animal foods is much higher, ranging from 70 to 100 mg per gram of protein. These relationships thus permit the estimation of lysine value from considerations of the amounts of animal protein and cereal protein [20]. Also, a further variable is the possible interaction between protein and food energy availability which may affect the protein value of diets when food energy is limiting to a significant degree. Thus, the additional effects of food energy deficiency on protein utilization could well be seen on the very poorest [22].

The analysis of lysine intake by sex reflected that lysine intakes of female respondents are lower as compared to the intake of males. One study measured the lysine requirement in women and reported an influence of the menstrual cycle phase (35 and 37.7 $mg \cdot kg^{-1} \cdot d^{-1}$ during the follicular and luteal phase, respectively), a difference that was ascribed to hormonal factors. In terms of the difference in the lysine intake between males and females, very limited studies give particular focus on specific amino acids. However, mean intake of amino acids are parallel to the protein intake. The results of the study confirm the data as revealed in the 2013 National Nutrition Survey that protein intake of males were higher compared to females. The human lysine requirement is the one of the essential amino acids focused on as subject of current collaborative international research and future agreement on the actual value is essential for the assessment, on a global basis, of those at risk for deficiency, as well as for the assessment of whether diets meet essential amino acid needs. Thus, reference standards are needed for comparison [20]. In the FAO Expert Consultation recommendations in 2011, amino acid requirements in different conditions and circumstances such as in varying population age groups and sex were determined.

5. Conclusion

The lysine intakes of Filipinos revealed that the prevalence of inadequacy is present in all age groups but higher prevalence was observed among the 6 to 11 month old infants. The prevalence of inadequacy was higher among the females, the poorest sectors, and in the rural areas as compared with the richest and urban areas, respectively.

It is crucial to focus future actions in improving diet quality of 6 to 11 month old agegroup to prevent retarded growth.

Limitation of the Study

Lysine intake was calculated based from all food and beverages only, dietary supplements were not included. About 60% of the infants age 6 -11 months were breastfed; however, human milk was also not included in the diet of the infants.

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References

[1] Wu, G., "Amino acids: metabolism, functions, and nutrition," *Amino Acids*, 37. 1-17. 2009.

[2] Brown, MJ, “Animal vs plant protein-what's the difference,” June 17, 2017. Available: https://www.healthline.com/nutrition/animal-vs-plant-protein. [Accessed May 6, 2020].

[3] American Society for Nutrition, “Protein complementation,” March 22, 2011. Available: https://nutrition.org/protein-complementation/. [Accessed April 6, 2018].

[4] Griffith, R.S., Walsh, D.E., Myrmel, K.H., Thompson, R.W. and Behforooz A., "Success of L-lysine therapy in frequently recurrent herpes simplex infection," *Dermatologica*, 175(4). 183-90. 1987.

[5] Ghosh, S., Smriga, M., Vuvor, F., Suri, D. and Mohammed, H., "Effect of lysine supplementation on health and morbidity in subjects belonging to poor peri-urban households in Accra, Ghana," *Am J Clin Nutr* , 92(4). 928-939. 2010.

[6] Zhao, W., Zhai, F., Zhang, D., An, Y. and Liu, Y., “Lysine-fortified wheat flour improves the nutritional and immunological status of wheat-eating families in northern China," *Food Nutr Bull*, 25(2). 123-129. 2004.

[7] Hussain, T., Abbas, S., Khan, M.A., and Scrimshaw, N.S., "Lysine fortification of wheat flour improves selected indices of the nutritional status of predominantly cereal-eating families in Pakistan," *Food Nutr Bull*, 25. 114-122. 2004.

[8] Rudd, C.E., Trevillyan, J.M., Dasgupta, J.D., Wong, L.L., and Schlossman, S.F., "The CD4 receptor is complexed in detergent lysates to a protein-tyrosine kinase (pp58) from human T lymphocytes," *Proc Natl Acad Sci USA*, 85(14). 5190-5194. July. 988.

[9] Food and Agriculture Organization, "Report of an FAO expert consultation-Dietary protein quality evaluation in human nutrition," Publishing Policy and Support Branch, Office of Knowledge Exchange, Research and Extension, FAO, Viale delle Terme di Caracalla, 00153 Rome, Italy. 66. 2013.

[10] Tome, D., and Bos, C., "Lysine requirement through the human life cycle," *Journal of Nutrition*, 137(6). 1642s-1645. 2007.

[11] Kurpad, A.V., Regan, M.M., Raj, T., Vasudevan, J., Kuriyan, R., Gnanou, J., and Young, V.R., "Lysine requirements of chronically undernourished adult Indian men, measured by a 24-hr indicator amino acid oxidation and balance technique," *Am J Clin Nutr* , 77(1). 101-8. 2003.

[12] Pennstate Hershey, "Lysine," 2015. [Online]. Available: http://pennstatehershey.adam.com/content.aspx?productId=107&pid=33&gid=000312 [Accessed March 1, 2020].

[13] Food and Nutrition Research Institute- Department of Science and Technology (FNRI-DOST), "Philippine Nutrition Facts and Figures 2013: 8th National Nutrition Survey," Food and Nutrition Research Institute, Taguig City, Metro Manila, Philippines. 2015.

[14] Carriquiry, A., "Assessing the prevalence of nutrient inadequacy," *Public health Nutr*, 2(1). 23-33. 1998.

[15] Lopez-Olmedo, N., Carriquiry, A.L., Rodriguez-Ramirez, S., Ramirez-Silva, I., Espinosa-Montero, J., Hernandez-Barrera, L., Campirano, F., Martinez-Tapia, B., Rivera, J.A., "Usual intake of added sugars and saturated fats is high while dietary fiber is low in the Mexican population," *J Nutr* , 146(9). 1856S-65S. 2016.

[16] World Health Organization, Food and Agriculture Organization of the United Nations, United Nations Library, "Joint FAO/WHO/UNU expert consultation on protein and amino acid requirements in human nutrition," World Health Organization, Geneva, Switzerland .2007.

[17] Denney, L., Angeles-Agdeppa, I., Capanzana, M.V., Toledo, M.B., Donohue, J. and Carriquiry, A., "Nutrient intakes and food sources of filipino infants, toddlers and young children are inadequate: findings from the National Nutrition Survey 2013," *Nutrients*, 10(11). 1730. 2018.

[18] Uauy, R., Kurpad, A., Tano-Debrah, K., Otto, G.E., Aaron, G.A., Toride, Y., Ghosh, S., "Role of protein and amino acids in infant and young child nutrition: protein and amino acid needs and relationship with child growth," *J Nutr Sci Vitaminol*, 61. S192-S194. 2015.

[19] Huey, S.L., Mehta,S., "Stunting: The Need for Application of Advances in Technology to Understand a Complex Health Problem," *EBiomedicine*,6. 26-27.2016.

[20] Pellett, P.L., "World essential amino acid supply with special attention to South-east Asia," *Food Nutr Bull*, 17(3). 1-31 .1996.

[21] Heack, J., Nieves, J.W., Chen, Y., Parvez, F., Brandt-Rauf, P.W., Howe, G.R. and Ahsan, H., "Protein and amino acid intakes in a rural area of Bangladesh," *Food Nutr Bull*, 31(2). 206-213. 2010.

[22] Pellett, P.L., and Ghosh, S., "Lysine fortification: past, present, and future," *Food Nutr Bull*, 25(2), 107-113. 2004.