

Assessing the Environmental Impact of White Bean Consumption in Sulaimani City: A Comprehensive Life Cycle Assessment Tool

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Abstract

Climate change is greatly related to greenhouse gas emissions (GHGs) where the agricultural sector is responsible for approximately 14% of total emissions. In this research Life Cycle Assessment (LCA) methodology was considered, and the carbon footprint of dry bean in the supply chain process in Sulaimani was expressed. Data was collected via an online survey and face to face administration of questionnaires among a sample of 386 adult city dwellers in Sulaimani. This paper provides for the first time a comprehensive evaluation of the life cycle environmental impacts of dry white beans consumed in Sulaimani city. The system boundary was set to cradle-to-grave with a functional unit of using different amount of dry beans in the Sulaimani household, two methods of cooking dry white beans at the consumer stage tested in the study were cooking in normal pot and pressure cooker. The aim of this research is to assess the environmental impacts of the consumption of domestic and imported white beans by using LCA methodology. The results illustrated that great number of the residents bought imported white beans which have huge impacts on the environment. Even though the dweller's soaking the beans precooking, it boils for long time (4-6 hours) with mean (1-2 hours) that means using more energy (gas or electricity) and this stage is the hot spot of consumption white bean. Moreover, the majority eat 1-2 meal/week with amount of ¼ Kg. The research conducted that cooking time and energy use efficiency as two parameters that affect the consumption at the consumer stage. Further research is required to investigate the impact of cultivation beans in Kurdistan, Iran, and Turkey as these two countries main export for bean to Sulaimani and comparison among them.

Keywords: White bean, LCA, Environment, Sulaimani residents

Introduction

Unless the sector of agriculture is considered as one of the great sectors of economic development in the whole world, it is responsible for vital pollution [1]. Agricultural pollution has become an extremely controversial issue all around the world, especially in developing countries; because of huge amount of chemical substances such as insecticides, herbicides, and fertilizers are used in agricultural. Which is main cause for water pollution, even it is greater than industrial sources; 60 presents of underground water in china are not suitable for human consumption [2]. Agriculture is an emitter of

huge amount of greenhouse gases (GHGs) which produces around 14% of total GHG emissions [3]. Furthermore, Food production and consumption cause many environmental impacts such as land use, energy use, and eutrophication, for instance, animal-based food products have greater land use, and huge impact on eutrophication and climate compared to plant-based food products [4] and [5]. Besides that, the consumption and the production of food are responsible for about 25% of carbon footprint in Europe [4]. Technologies play vital role in environmentally friendly agricultural

production as required by social which assist preserve sustainable environment while achieving food safety by providing high quality food [6].

Bean with different names which are kidney bean, bush bean, haricot bean, snap bean, and navy bean (*Phaseolus vulgaris* L.) usually known as rajmash in India, is an important legume and a kind of legumes which consumed worldwide [7, 8, and 9]. Its dry seed contains 425 mg phosphorous, 21.1 percent protein, 1.7 percent fat, 69.9 percent carbohydrates, 12.4 mg iron, and 381 mg calcium per 100 g of edible part [7]. As well as being crucial sources of fibre, micronutrients, various phytochemicals, essential amino acids, starch, oligosaccharides and simple sugars are present in legume seeds. Moreover, they have appreciable quantity of potassium and magnesium [10]. For some reasons, consuming dry beans have several advantages; for example, according to the research that achieved by [11] found that kidney bean consumers had better waist circumferences, better body weights, and lower systolic blood pressure, and better overall levels of nutrient intake in comparison to non-consumer. The consumption of Legumes is a common and useful part of the human diet and contributing to health. High-income consumers ate considerably less lima, pinto, and navy beans than low-income consumers [12]. The main reason for avoiding consuming dry bean is as the consumers believe that it is a great source of flatulence or excessive intestinal gas. While there are great researches and the 2010 Dietary Guidelines for Americans supports the advantage of a plant-based diet, specially legumes in the decreasing the risks of chronic disease. In addition, this study found that consumers could be exaggerated in their concern about extreme flatulence from consumption beans [13] and [14]. Low-income countries produce about 8.5 million metric tons of dry beans which are nearly over three-quarters of the world production annually. Moreover, bean is the main food in developing countries and

North America. The production of bean in North America is slightly higher than in Europe [15]. As the requirement of cultivation of white beans according to [16 and 17] revile that the adequate soil in texture is loamy, low PH and rich in organic matter relatively the best temperature for growing is (18-29°) cilices; furthermore, beans do not or hardly demand fertilizers. It is very important to reduce the use of chemical substances in beans' cultivation as it assists to increase the soil fertility through their nitrogen-fixation capacity in turns reduce the demand for fertilizers and support a sustainable food system [18]. However, environmental factors can have impact on the bean's productions especially biotic such as post-harvest pests and diseases and yield; and abiotic for instance inadequate soil fertility, drought, flooding, cold and heat stress [19]. Additionally, the consumption of dry beans has risen prominently in the USA over two decades ago [12]. Whereas, the Nutrients bioavailability could be increased by soaking, fermentation, and sprouting [10]. For this reason, a significant number of people consume navy beans, which are a suitable source of protein. Hence, plant food-based choices, is more environmentally sustainable food consumption [5]. Nevertheless, some of people cannot be able to have beans due to toxicity or allergenicity, the toxicity of dry bean could be separated into two subcategories: toxicity caused by its saponins, phytates, lectins and protease inhibitors or allergenicity that is caused by its allergenic proteins [20].

Life Cycle Analysis (LCA) is a management tool used to assess the environmental impact of each stage in the life of a product from the raw materials used to create the product, the production process, packaging and distribution, to final use and disposal of the product (waste management). The end result is an evaluation of the overall environmental impact associated with a product or service. LCA is sometimes also referred to as the “**cradle to grave**” approach. This system tool provides information about the environmental

effects including effects on ecosystems, depletion of resources, toxicity, and global warming associated with the inputs and outputs [21]. According to [21] there are different stages in LCA method which include: first, input; Pesticide and fertilizers Production, energy, and machinery and packing, second; Farming and using input in the farms and field emission, third; distribution and storage using different methods of transportation such as truck, ship, plane and fourth; consumption and waste disposal (Home transport, storage, cooking and consumption). The study was done by [22] which used LCA that includes main stage: agricultural production, transportation by road and by plane utilizing 1 Kg of raw bean processed as functional unit. Found that air-freight had great impact which is identified as hot spot, on the other hand the kinds of farm has different effects for example medium farm gain the least effects, water, fertilizer, land use. Further research is required to be done in terms of using LCA in the consumption stage (extend LCA in consumption stage). This research concentrates on consumption stage of white bean in Sulaimani city. According to the study, which was done by [21] showed that the

consumption stage in LCA study has been ignored. Life cycle analysis used in the study as a beneficial tool to identify potential environmental impacts for the consumption of white beans in Sulaimani city, as beans are classified as the great economic activities at the area for its huge consumption; besides, to identify the hot spot in the LCA of the consumption of beans in order to optimize the environmental footprint. The aim of this research is to assess the environmental impacts of the consumption of domestic and imported white beans by using life cycle assessment (LCA) methodology. The consumer stage is the last stage in the Life cycle Assessment LCA model (cradle-to-grave). It involves beans purchasing from stores, transportation, cooking and consumption of pulses, and waste generation [23].

Methods and Methodology

Sulaimani is Kurdish city in Iraqi Kurdistan, which is classified as the third top city crowded with population of about 651000 in 2015 and recently it is approximately 801,000 in 2023, it is expected to continue to increase to about 1,089,000 by 2034 as has been shown in figure 1 [24].

Sulaimaniya Urban Area Population Graph

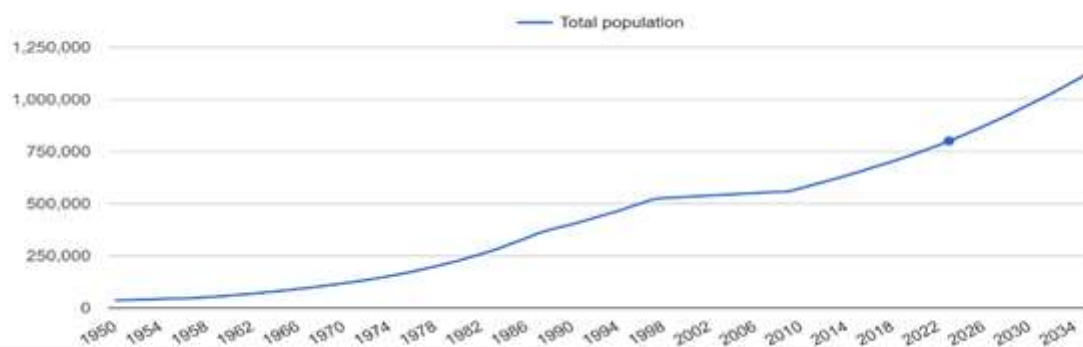


Figure 1: Sulaimani population (source:[24])

The Research was conducted in Sulaimani in 2023; the research community consists of residents in Sulaimani city. Primary data was used for this research; using a semi-structure which is a combination of open and closed questions. The questionnaire is administered in a random sampling technique. Face to face administration of questionnaires and online google form was conducted to gather information about people consumption of white dry bean. The total number of people in

the sample was 386 residents. The questionnaire consists of two parts: The first part; included personal questions (age, gender, education level, career, and economical states). The second part; of the questionnaire categorized to: consumption of white dry bean, the way of cooking it, the reasons for consuming white beans, and their interest in buying local or imported beans. Moreover, Data were entered and analyzed using SPSS Version 22 and Excel.



Transport to and storage includes the transport step from the farm or from the place of production (countries) to place of consumption. an average road transportation 907 km, 2,259 km from Iran, and Turkey respectively when they are the most adopted countries for imported white bean, while distance from Bulgari is nearly 2,685 km. In addition, during the transportation the white bean should be keep it in cool place which require air conditioner in summer as KGI has hot summer.

Transport to retailer and storage: similar as above, however related to the retailing step. At this stage include the losses of food.

Transportation of white beans to home by the consumer: energy use for transportation

such as using (Bus, Taxi, Cars) weighed according to the average KRI consumer shopping of beans. Furthermore, the consumer used to purchase from Bazar or market by using bus or their own cars.

Storage at home: energy use at home for storage, in winter keep it in room temperature is adequate while in summer need cool place.

Cooking: which require water and Energy related to cooking modes (normal pot, and pressure cooker), considering electric and gas used for cooking, time of boiling.

Solid and Liquid waste management: wastewater from boiling white beans is sent to sewer, whilst solid cooking waste (white beans) are sent to disposal in landfill.

Results and Discussion

Table (1) Personal Information

Personal Information	Item	Frequency	Percent %
Gender	Male	205	53.1
	Female	181	46.9
Marital Status	Married	190	49.2
	Single	193	50
	Others	3	0.8
Job	Jobless	46	11.9
	Student	77	19.9
	Housewife	32	8.3
	Government employee	113	29.3
	Non-government employee	48	12.4
	Own business	55	14.2
	others	15	3.9
living Status	Good	133	34.5
	Bad	14	3.6
	Very good	17	4.4
	Very bad	3	0.8
	Middle	219	56.7
Family Member	1-2 Member	43	11.1
	3-4 Member	173	44.8
	5-6 Member	124	32.1
	7-8 Member	39	10.1
	over 8 Member	7	1.8
Education	Bachelor	174	45.1
	diploma	72	18.7
	High diploma	2	0.5
	PHD	15	3.9
	Secondary School	50	13
	Primary School	2	0.5
	Master	47	12.2
	High school	23	6
Illiterate	1	0.3	
Total		386	100

Source: Author's survey (2023) and SPSS Result

The great number of respondents are female, they are single and working in government sector. The economic level of large number of participated is medium, with their family

member consist of (3-4) member, the majority

have bachelor's degree.

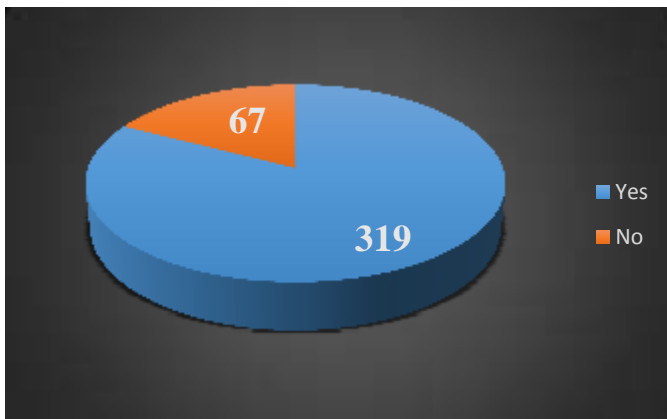


Figure 1: Consuming White Bean

The chart above demonstrates that the highest number of participants are consuming beans which is about (319); however, the lowest do not eat beans for some reason as it is clear in table number (2).

Table (2) The reasons for non-consuming dry bean

The reason for non-consuming dry bean	Strongly agree		Agree		Natural		Disagree		Strongly disagree	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
I do not like it	29	7.5	24	6.2	11	2.8	1	0.3	2	0.5
Take long time to prepare	18	4.7	19	4.9	24	6.2	4	1	2	0.5
I have allergies	11	2.8	21	5.4	25	6.5	5	1.3	5	1.3
It is bad for my health	17	4.4	19	4.9	23	6	3	0.8	5	1.3
Doctor recommended to not have it	14	3.6	20	5.2	21	5.4	7	1.8	5	1.3

Source: Author's survey (2023) and SPSS Result

This table illustrates the reasons for non-consuming white dry beans, the highest number of respondents do not like it; in addition, 18 people state that it takes long time to be prepared. However, the lowest number of participants do not have it for health issue. Time for cooking beans is a problem for consumers for two main reasons: lack of fuel and time availability. Beans demand long time for cooking to be prepared which is not

preferable by many consumers, as consumers prefer convenient foods that is easy to prepare [25] and [26]. In addition, approximately 44 percent of respondents strongly agreed that dry beans require much time for preparation compared with other major food [27] and [28] and require fuel or electricity which could be a limit factor in low income families for consumption beans [27].

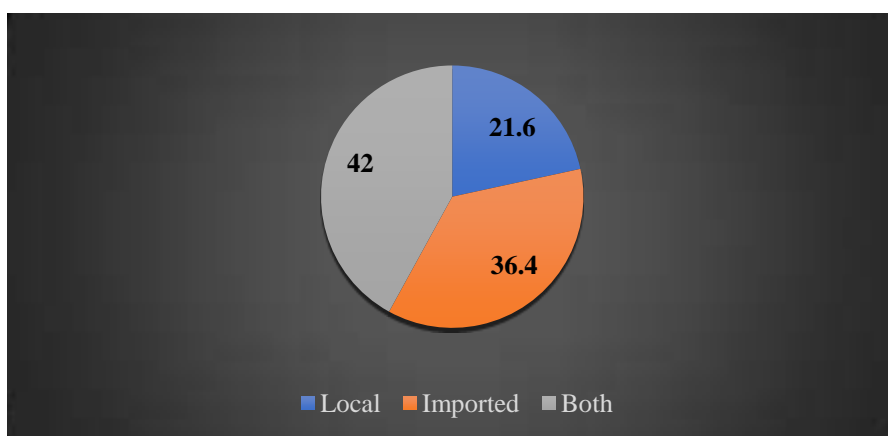


Figure 2: Kinds of White Bean Consume

Pie chart demonstrates that the smallest percentage nearly 21.6% buy only locally bean. Whilst 36.4 % buy imported beans; additionally, the largest percentage buy both (42%). One of the main results of this research is the confirmation that working with ‘food miles’ as an indicator of environmental effects for food products is potentially misleading: imported products may have greater

environmental impacts than domestic produces. As mentioned by [21] Imported products by plane illustrates higher environmental effects than domestic produce. Moreover, as discovered by [29] domestic production of soybean meal instead of imported could have a positive influence, especially to produce and used on farm legumes.

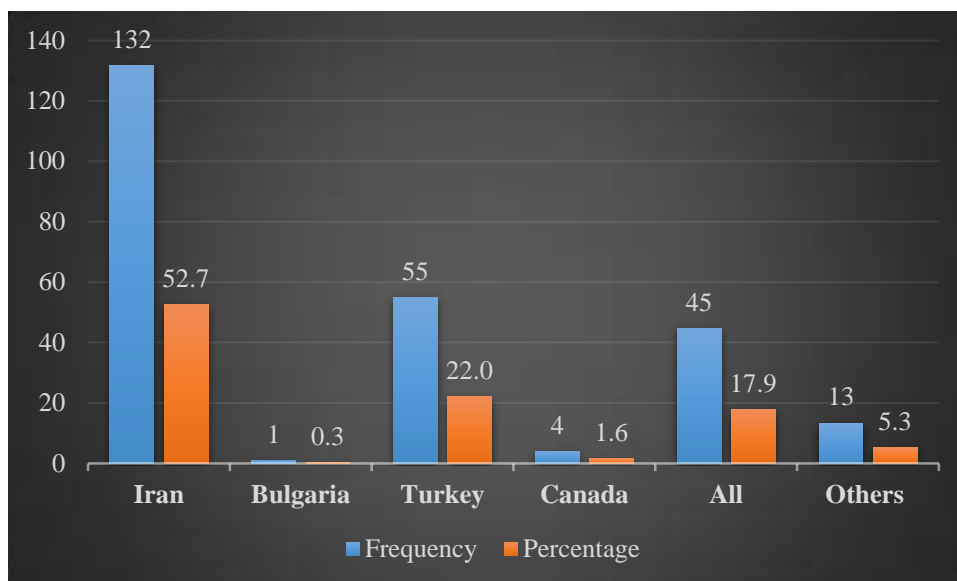


Figure 3: Countries of Imported White Beans

The bar chart reveals that the most consumers buy beans that have been imported from Iran represent (52.7%), followed by Turkey represent (22%). However, small ratio of respondents buy imported from Bulgaria and Canada representing (0.3% and 1.6%) respectively. Changing consumption use changes. According to a study by [31] published in "science," the carbon footprint of

behaviours from imported to locally products decline greenhouse emission related to transport activity and international trade and assist to reduce carbon footprint [30]. Imported White beans can have a significant impact on the environment due to factors such as transportation emissions and land food products can vary greatly depending on their origin and transportation methods.

Table (3): Imported white bean has impacts on environment

Respondents	Frequency	Percent
Strongly Agree	66	20.7
Slightly Agree	119	37.3
Agree	87	27.3
Disagree	33	10.3
Strongly Disagree	14	4.4
Total	319	100

Source: Author's survey (2023) and SPSS Result

The table establishes that 119 (37.3) are slightly agree that imported beans have negative effects on environment, while 87 (27.3%) agree, and 66 (20.7%) are strongly agree. However, the minority disagree is 33 (10.3%), and strongly disagree 14 out of 319 indicating (4.4%). Recently, the issue of the relationship between trade and the

environment has increased with the world expansion, the international trade has drawback impacts on environment such as, ozone depletion, global climate change, hazardous wastes, and forest degradation which led to loss of ecosystem services and natural resources [32] and [33]. Moreover, according to [34] the transportation of pulse

has crucial impacts on environment especially when they were packaged and processed far from the final destination. Imported beans often involves long-distance transportation, which contribute to GHG emissions from fossil fuel consumption. This transportation-related impact can be substantial, particularly

if beans are sourced from regions with a significant geographical distance from consumer market [31]. The study done by [33] discovered that the consumption choices in a region have impacts on the ecosystem services at huge locative scale.

Table (4) Types of White Bean Buy from Market

Respondents	Frequency	Percentage
Un-Packaged	159	49.8%
Packaged	129	40.4%
Canned	31	9.7%
Total	319	100%

Source: Author’s survey (2023) and SPSS Result

The table exhibits that the highest percentages include buy un-packaged dry bean signifying 49.8% and packaged bean was 40.4%; whereas the lowest percentage answered they buy canned bean denoting 9.7%. Because of the think canned products have adverse impacts on health and cause cancer disease. The research was done by [18] demonstrated that less accultured Latinas frequently consumed beans, preferred dry bean over canned bean as they have negative attitude towards canned one, while more acculturated/biocultural white women preferred canned beans. Hence, acculturation level and ethnicity have a great role in patterns

and attitudes of purchasing dry or canned beans [18]. Dry beans are purchased uncooked from the market and supermarkets in both forms canned and dry, in additionally, consumers in the United State are preferred canned one because of their convenience in contrast to Latin America, they do not prefer canned or other prepackaged options [18]. Furthermore, processing and packing of legumes are vital steps in the supply chain that required to be scrutinized, for that it is important to enhance the environmental awareness and action among consumers, food industries and purchasers to gain more sustainable sourcing of legumes [34].

Table (5) The amount of Consumption White Bean weekly

Respondents	Frequency	Percent
1 meal	93	29.2
1 – 2 meals	142	44.5
3 – 4 meals	71	22.3
5 – 6 meals	10	3.1
8> meal	2	0.6
Missing	1	0.3
Total	319	100

Source: Author’s survey (2023) and SPSS Result

The majority number of consumers had white bean 1-2 meals in a week, and 29.2 percent

had dry bean at least one meal in a week. At the same time, 3-4 and 5-6 meals/week

representing (22.3%, and 3.1 %) respectively of the respondents; however, only 2 out of the total had white beans more than 8 meals/week. On the other hand, 0.3% indicates no response. The study which was done by [18] showed that approximately 66% of adults are

having beans at least one time/week; male is consuming 1 cup while female $\frac{1}{2}$ cup per week, however, it has been recommended to consume $1\frac{1}{2}$ to 2 cups of beans per week, in addition, fewer than 11 percent of the residents ate 5 time or more in a week.

Table (6) The amount of cooking White Bean

Respondents	Frequency	Percent
More 1 kg	4	1.3
more1/2kg	47	14.7
less 1Kg	23	7.2
less 1/2Kg	102	32
$\frac{1}{4}$ Kg \geq	143	44.8
Total	319	100

Source: Author's survey (2023) and SPSS Result

The greatest number of participants cook more than $\frac{1}{4}$ Kg and less than $\frac{1}{2}$ kg which are denoting (44.8 and 32 percent) respectively, and 14.7% cook more than $\frac{1}{2}$ kg. However,

only 1.3% cook more than a kilogram. Moreover, 7.2% cook nearly 1 kg of dry beans.

Table (7) Cooked Bean Remaining

Respondents	Frequency	Percent
Very Often	101	31.7
Rarely	206	64.6
Never	12	3.8
Total	319	100

Source: Author's survey (2023) and SPSS Result

The table explains that the largest ratio of respondents 64.6% state that seldom do not consume the total amount of cooked beans,

and very often cooked dry beans remains represent 31.7%. While only 3.8% states never remain cooked beans.

Table (8) The amount of remaining cooked Bean

Respondents	Frequency	Percent
More 1/2	10	3.1
1/2	45	14.7
less 1/2	252	82.1
Total	307	100

Source: Author's survey (2023) and SPSS Result

The table illustrates that the greatest proportion of participants state that less than half and half of cooked white bean remain after the meal which is representing 82.1%

and 14.7% respectively, whilst very small ratio 3.1 percent state remains more than a half.

Table (9) Usage of remained cooked Bean

Respondents	Frequency	Percent
Used for their consumption	211	68.7
give it to their beards	26	8.5
give it to wild animals	7	2.3
Throw away	52	16.9
Others	11	3.6
Total	307	100

Source: Author’s survey (2023) and SPSS Result

The Table shows that the highest percentage, about 68.7% the use the remained cooked beans for their consumption, nearly 16.9

percent throw it away. However, 34 participants used to feed animals.

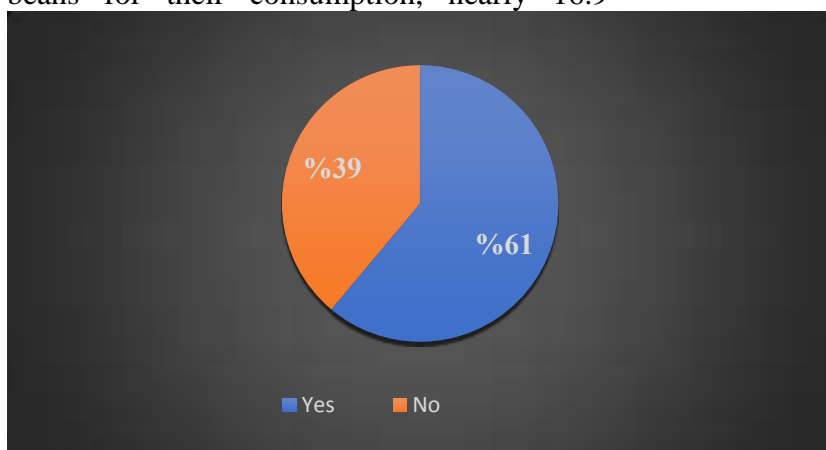


Figure 4: Soaking White Bean precooking

The Pie chart demonstrates that the highest rate of respondents soaking white beans before cooking that is 61.1%, whereas the lowest do not soaking dry bean representing 38.9%. There are various methods for cooking beans in different culture, for example some people

in some culture soaked beans in water for a while between 8-12 hours or overnight, while other culture cooked it without soaking, in addition, there are people cooking it in boiling water [35].

Table (10) Time of Cooking White Bean in Pressure Pot

Minutes of cooking in pressure pot	Frequency	Percentage	
15	8	2.51%	Minimum = 15
20	18	5.64%	
25	6	1.88%	
30	89	27.90%	
35	2	0.63%	
40	14	4.39%	
45	40	12.54%	Maximum= 240
50	11	3.45%	
60	82	25.71%	
70	5	1.57%	
80	1	0.31%	
90	11	3.45%	Mean= 78.75
120	21	6.58%	
160	1	0.31%	
180	9	2.82%	
240	1	0.31%	
Total	319	100.00%	

Source: Author's survey (2023) and SPSS Result

The table above demonstrates that the maximum time for cooking bean in pressure cooker is 240 minutes (4 hours), while the minimum is about 15 minutes. Moreover, the mean is approximately 78.75 minute (01:18 hours). Environmental impact of dry beans varied with different methods of cooking [23]. Cooking stage for products which are cooked such as beans has significant impact on environment that might be because consumer behaviour for example cooking for long time or less, using vary kitchen appliances such as

normal pot or pressure pot. Energy consumption during cooking was the main factor for cradle-to-grave effect of pulses and for contribution of consumer stage. Great energy use efficiency and shorter cooking time has less impacts than longer time of cooking and use more energy [23]. Additionally, the major hotspot in the carbon footprint of White dry bean comes from energy consumption in processing.

Table (11): Time of Cooking White Bean in Normal Pot

Minutes of cooking in normal pot	Frequency	Percentage	
60	106	33.23%	Minimum=30
120	71	22.26%	
180	43	13.48%	
90	26	8.15%	Maximum=360
45	19	5.96%	
70	11	3.45%	
240	9	2.82%	
150	8	2.51%	
30	8	2.51%	Mean=119.5
40	5	1.57%	
50	4	1.25%	
160	2	0.63%	
190	1	0.31%	
360	1	0.31%	
140	1	0.31%	
130	1	0.31%	
35	1	0.31%	
75	1	0.31%	
105	1	0.31%	
Total	319	100.00%	

Source: Author's survey (2023) and SPSS Result

The table above reveals that the maximum time for cooking dry bean in normal pot is 360 minutes (6 hours), while the minimum is about 30 minutes. Moreover, the mean is approximately 119.5 minute (nearly 2 hours), which is long time; however, the residents state that prefer normal pot because of bean in more tasty and keep its shape. Therefore, this

Conclusion

Agriculture has vital impacts on the environment, with the increasing in the population size, therefore, the need for agriculture would rise to provide food for dwellers. Beans is one of the most important crops and widely adopted in Sulaimani city especially the imported one which led to adverse impacts on the environment through producing great amount of Green House Gases (GHGs) in transportation via using fossil fuel.

study exposed that the major hotspot in the carbon footprint of White dry bean comes from energy consumption in processing of cooking. This the same result as this research, which was achieved by [23] who found that consumption stage as the hot spot for environmental effects in the pulses supply chain in the USA.

In addition, Transport to retailer and storage, and transportation of white beans to home by the consumer. Moreover, cooking stage which has been identify as the hot spot due to take long time to be prepare that is required more energy (gas or electricity). Disposal stage, most of the respondents consume the rest amount of beans and some of them used to feed animals that reduce the amount of waste generation and producing (GHGs). This study used LCA in consumption stage to assessment

the impacts of White beans. This research recommends that it is important for consumers and policymakers to consider these environmental implications and explore sustainable sourcing practices to mitigate the negative effects of importing beans on the environment. further research is very important to consider the impact of bean cultivation (in farm stage) in Kurdistan, Iran, and Turkey as these two main exported countries to Sulaimani city and make comparison among them.

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