An - Najah Univ. J. Res. (N. Sc.) Vol. 29, 2015

Life Cycle Assessment of Olive Oil Tin and Plastic Containers

تقييم دورة حياة العبوات البلاستيكية والتنك المعدني المستخدمة لتعبئة زيت الزيتون

Yahya Saleh

يحيى صالح

Industrial Engineering Department, An-Najah Business Innovation & Partnerships Center (NaBIC), An-Najah National University, Nablus, Palestine

Email: ysaleh@najah.edu

Received: (28/7/2013), Accepted: (17/9/2014)

Abstract

For a long period of time, Palestine has witnessed significantly noticeable shortages and scarcities of natural resources, namely, water and energy resources. Many industries adversely contribute in the continuous consumption and depletion of such natural resources. Among these, there are the packaging materials industries producing plastic and metal packaging containers for holding liquid products. Examples of such containers are tin and plastic containers used for packaging and storing olive oil in Palestine. These primary two packaging systems differ in their environmental impacts during the stages of processing, manufacturing, distribution, transportation, usage and disposal. More specifically, they differ in consumption of natural resources such as water, energy, and land use (solid wastes generation), as well as in their contribution to human toxicity and health problems (dust) and resulted industrial noise. This work aims at evaluating and comparing the potential environmental impacts of tin and plastic containers of olive oil via employing life cycle assessment (LCA) based on International Standardization Organization (ISO) standards (namely, ISO 14040, ISO 14041, ISO14042, and ISO 14043). The life cycle inventory and impact assessments considered the above-mentioned significant environmental domains (water, energy, solid waste, dust and industrial noise) in conducting the LCA. Within the boundaries of both systems, the LCA analysis showed that tin containers (16 Ls) outperformed plastic containers (16 L) in terms of having less environmental impacts.

Keywords: Life cycle assessment, ISO 14040-14043, olive oil, plastic containers, tin containers.

ملخص

تشهد فلسطين وبشكل كبير نقصاً ملحوظاً وندرة حادة في الموارد الطبيعية، خصوصاً موارد المياه، والطاقة والمواد الخام. تسهم العديد من الصناعات الفلسطينية سلباً في الاستهلاك المستمر وفي نضوب هذه الموارد الطبيعية. من بين هذه الصناعات تلك المنتجة لمواد التعبئة والتغليف البلاستيكية وكذلك الحاويات المعدنية المستخدمة في التعبئة والتغليف لبعض المنتجات السائلة. ومن الأمثلة على هذه الحاويات تلك المصنوعة من الصفيح (التنك) والبلاستيك على شكل عبوات تستخدم لتعبئة وتخزين زيت الزيتون في فلسطين. تختلف أنظمة التغليف هذه والمستخدمة لتعبئة زيت الزيتون هنا في فلسطين في تأثيراتها البيئية خلال مراحل التجهيز والتصنيع والتوزيع والنقل والاستخدام وكذلك في مرحلة التخلص منها. وبشكل أكثر تحديداً، فإنها تختلف في استهلاك الموارد الطبيعية مثل المياه والطاقة، واستخدام الأرض (إنتاج النفايات الصلبة)، وكذلك في مساهمتها في السمية البشرية والمشاكل الصحية (الغبار) وإنتاج الضوضاء الصناعية. تهدف هذه الدراسة إلى تقييم ومقارنة الآثار البيئية المحتملة والناتجة عن عبوات الصفيح والبلاستيك المستخدمة في تعبئة زيت الزيتون من خلال تقييم بيئي لدورة الحياة (LCA) استناداً إلى معايير (ISO 14040, ISO 14041, ISO 14042, ISO 14043) . اعتمدت هذه الدراسة في إجراء تقييم دورة الحياة لنظامي التعبئة والتغليف على تحليل المخزون ودورة الحياة وعمليات تقييم الأثر في المجالات البيئية التالية: استهلاك المياه والطاقة، إنتاج النفايات الصلبة، والغبار والضوضاء الصناعية.وأظهرت نتائج التحليل تفوق اناء القصدير (16 ليتر) على إناء البلاستيك (16لترا) من حيث وجود تأثيرات أقل على البيئة.

1.0 Introduction

The Palestinian environment in the West Bank and Gaza Strip suffers a great deal due to the different human activities carried out in the region. Also, the continuous population growth and the glaring negligence of environmental issues during all years under occupation add to the suffering of environment. In addition to that, the frequent Israeli closures of the West bank and Gaza Strip make the problem get worse through impeding the economic and social activity that would frequently cripple life in the Palestinian cities and villages.

These causes resulted in various environmental disasters and declination of water quality and environmental health. The problem of water resources, open and uncontrolled dumping of solid waste and energy in Palestine are considered the most important problems of environment that requires taking of urgent and direct procedures. Nowadays, companies are faced with ever stricter environmental controls and changing markets in which consumers are becoming increasingly aware of environmental matters. Finding solutions to keep ahead of these issues is not an easy matter, which is why companies need tools to help them meet the challenges of tomorrow. Life-cycle assessment (LCA) is a tool as such.

LCA identifies the material, energy, and waste flow of a product over its entire life cycle, so that the environmental impacts can be determined. It can help companies to identify changes to their operations, including product design, which can lead to environmental benefits and cost savings, Harun *et al.* (2010). Many companies have used LCA and, as a result, they have reduced costs and improved the environmental performance of their organization and products.

The rest of the paper is organized as follows. Section two presents some related previous studies on LCA. The importance of this study is discussed in section three. In section four, problem definition and the study objectives are given. The LCA methodology is discussed in Section five, where the analysis and findings of the study are presented. The last section which is section six closes the article with the study conclusions and recommendations.

2.0 Literature Review

Studies on investigating the life cycles of products, services and materials started in late sixties of the last century. The main focus of such studies was mainly on energy efficiency, raw materials' consumption and to a modest extent on disposal wastes, (Jensen *et al.*, 1997). For example, in 1969, the Coca Cola Company in the USA supported a study aiming at evaluating the resources consumption as well as their associated environmental burdens of beverage containers. During the same period, Europeans were working on developing a similar inventory approach which was later known as "Ecobalance". Ian Boustead conducted a study in the UK in 1972 to compute the total energy used in the production of various types beverage containers including plastic, glass, steel and aluminum. Afterwards, he developed his methodology to encompass the applicability to diverse types of materials and he published this in the Handbook of Industrial Energy Analysis in 1979. The interest in LCA has witnessed a real change in 1980's and 1990's to include a broader range of industries and applications (Jensen *et al.*, 1997). The swift increase of interest in such a 'cradle to grave" approach of assessing the environmental impacts of materials and products was obvious in the 1992 UN Earth Summit. People agreed that the LCA methodologies are among the most promising effective and efficient tools to be exploited in assessing the environmental burdens of materials and products in a comprehensive way. Literature is very rich with many studies on using LCA as a tool for comparative analysis of environmental releases from diverse products and materials. One study conducted by Mata and Costa (2001) utilized LCA to assess the environmental impacts associated with the returnable and non-returnable glass beer bottles. The inventory analysis was based on data obtained from two Portuguese companies (a glass bottles producer and a brewery). In their environmental impact assessment, they focused on both the potential ecological and eco toxical effects of the emissions. Yasuoka (1997) conducted an LCA study on PET bottles including open loop recycling. The cumulative gas (CO_2, NOx, and SOx) unit was used to calculate the total volume of greenhouse gas emission during the entire process of PET bottle from extraction of raw material to waste disposal.

Saleh (2003) has implemented an LCA study to evaluate and compare the potential environmental impacts of glass, aluminum (Al), and polyethylene terphthalate (PET) packaging materials of certain sizes of carbonated soft drinks (CSD). The study was conducted on the 1250 ml returnable glass bottles, the 330 ml Al- cans, and the 2000 ml PET bottles, where the life cycle inventory (LCI) of glass and Al was obtained from two Jordanian companies, while the LCI of PET was obtained from a Palestinian company. Six significant environmental impact categories in the Jordanian context are considered, namely, abiotic resources (water, energy), land use (solid wastes), human toxicity, acidification, and global warming potential (GWP). Hakala *et al.* (1997) used LCA to compare between biopolymer and traditional diaper systems. The study was based on diaper product as biodegradable materials. One of the important outcomes of this study is that the differences between the impacts of the traditional and biodegradable diaper systems are small. An LCA study by Mangena and Brent (2006) investigated the environmental impacts associated with the preparation and production processes of different grades of coal (low and high grades) from opencast and underground mines in South Africa. Different mining methods used in coal extraction have different environmental impacts. In their work, they conducted an ISO 14040-based LCIA methodology to assess such impacts of mining processes. Xie *et al.* (2011) conducted an LCA to assess the environmental impacts in the life cycles of two milk packaging systems; PA-PE-Al laminated foil made from paper and polyethylene and aluminum foil and polyethylene. Data related to the two packaging systems was obtained from published literature as well as from site investigations. The results showed that the composite packaging system had a higher environmental impact than the plastic system.

Zhou *et al.* (2013) developed an improved methodology to assess the aquatic eco-toxic potential of brine disposed from seawater desalination plants. In their approach, which they called a group-to-group approach, a set of potential influential chemicals are identified; their aquatic eco-toxicity is calculated and their average environmental impacts are determined. The proposed approach is verified by investigating a case study which included the environmental impacts of organic, metal as well as inorganic chemicals. Another recent study by Bengtsson and Seddon (2013) considered the LCA of chicken production of a major poultry production in Australia. They conducted a comparative study to assess the environmental impact of a conventional and free-range chicken production for the purpose of reducing those impacts and their associated costs, improving the product, processes and supply chains of the poultry plant. Avadi and Freon (2013) reviewed the state-of-the-art literature on LCA in fisheries. Their study starts with an introduction of the LCA framework and energy used by fishing vessels and determining the environmental impacts of fisheries operations. The review ends with some concluding remarks and recommendations for the future developments of LCA in the fisheries and seafood sector in general.

3.0 Significance of the Study

Lack of public awareness, regulations, laws, information and professional capacity as well as institutional gaps are common factors which negatively affect the local environment especially in developing countries like Palestine, (Shaheen, 2013). The permanent Israeli occupation of the Palestinian land worsens and aggravates the environmental problems in Palestine. More specifically, the Israelis both in cities and in settlements negatively contribute to the depletion, pollution and contamination of the Palestinian natural resources in both West Bank and Gaza Strip via imposing full control on such resources. Waste waters generated from Israeli factories as well as residential waste water in their settlements are discharged without any minimal treatment to Palestinian residential and agricultural territories. Such illegal practices contribute to the contamination of groundwater aquifers, surface water reservoirs and agricultural soil properties in Palestine and eventually negatively affect the general quality of life and health of Palestinians. With continuously-increasing growth of populations in Palestine and with the continuously-increasing demands on natural resources (water and energy), environmental concerns in Palestine become more challenging. In the sequel, such a challenging problem results in an obstacle in front of economic and social development in Palestine. In particular, the Israeli occupation and the frequent closures as well as full control on Palestinians' lands and natural resources by Israelis make the situation worse and more sophisticated through impeding the economic and social activities in Palestine and consequently paralyzing the life in the Palestinian territories. In the following discussion, more elaboration on different negative environmental problems and practices associated with their impacts on natural resources in Palestine is presented. In particular, the current status of water, solid wastes, industrial wastes, landfill sites, recycling and energy in Palestine are considered. Table (1) summarizes the current status of some environmental items in the Palestinian context accompanied with some quantities based on the statistics obtained from the Palestinian Central Bureau of Statistics (PCBS) for the years from 2011to 2013. The importance of this study emerges from the fact that tin and plastic containers of olive oil, as primary packaging materials, need to be environmentally- assessed by an LCA methodology. Such an assessment will help decision-makers (manufacturers, transporters, users) to better select the most environmentally-friendly containers for olive oil in Palestine. In the following section, a clear definition of the problem is presented.

4.0 Problem Definition

Packaging of materials, goods and products is an essential feature in the demand supply chain. Packaging has beneficial and harmful impact on the environment. More specifically, packaging protects goods and products from contamination during transportation, handling and storage. On the other hand, during production of packaging, diverse natural resources are depleted and energy is consumed. Emissions from packaging production processes, transportation, recycling and disposal pollute the environment. Since there is an increasing interest in the sustainability of resources, policy makers in particular and public in general are highly urged to search for effective solutions to the environmental problems caused by packaging materials. This study focuses on the environmental assessment of tin and plastic containers of olive oil in Palestine. Olive oil is a seasonal product of the holy land of Palestine. It is planted almost in all lands of Palestine. It is harvested during October and November every year. Palestinian olive oil is characterized by a high quality competitive with the oil quality of other countries (Spain, Greece, Italy, Turkey, Syria, Jordan, and Lebanon).

Table (1): Current status of environmental related categories in Palestine.

Environmental Item	Current Status Description	Some Important Quantitative Statistics
Water	Availability and adequacy of fresh water resources with enough quantities and proper qualities in Palestine are considered as one of the most serious problems of environment. This requires immediate corrective actions. Also, the absence of successful wastewater management is considered one of the main root causes of water problem in Palestine. In particular, untreated wastewater intrudes to groundwater aquifers, contaminates and deteriorates the quality of water.	• Annual available water quantity in West Bank equals 139.7 millions m^3/year. • Needed quantities of domestic water in West Bank equal 128.2 million m^3. • Deficit in domestic supply in the West Bank equals 65.9 millions m^3/year. • Numbers of localities and polpuation in West Bank having no wastewater networks are 453 and 1,453,519; respectively,
Solid Waste	Solid wastes are badly treated in Palestine. As a result, solid wastes represent a min source for the pollution of water resources, soil, air, coast, as well as disfiguring the beauty of nature. Moreover, the risks of possible leakage of hazardous substances worsen the problem as leakages threaten the public health.	• Daily average of generated waste in the educational establishments in West Bank is 39.675 ton/day. • Daily average of generated waste in the health care centers in West Bank is 10.733 ton/day.

...continue table (1)

Environmental Item	Current Status Description	Some Important Quantitative Statistics
Industrial Waste	The existing industries in Palestine are still undeveloped and are categorized as small and medium enterprises (SMEs). Such industries are located in residential, agricultural and industrial zones. Several environmental problems exist in such areas including solid wastes generation as well as gas emissions. Generated solid wastes are usually treated by municipalities through incineration and landfills.	• Daily average of generated industrial solid waste in Palestine is 364.84 ton/day.
Dumping Sites	Open and uncontrolled dumping of solid wastes is a normal practice of treating solid wastes in Palestine. Most of them are chosen without taking into account hydro-geological and environmental considerations.	• There are more than 400 dumping sites in Palestine.

...continue table (1)

Environmental Item	Current Status Description	Some Important Quantitative Statistics
Recycling	A limited proportion of steel and glass scrap of generated solid waste is recycled. Scavengers can be found in the dumping sited especially at the dumping sites of Israelis wastes. Most of the domestic waste is organic; however, composting of waste is not largely practiced on a good scale.	• No concrete statistics could be obtained regarding recycling plants in Palestine. Nevertheless, one company, called the Palestinian Recycling Company (TADWEER) was established in 2010 for solid waste recycling with a 500 tons/day.
Energy	Palestine has a very small production of energy in terms of biomass, solar and electricity. Most of the consumed energy is imported from outside. About 95% of electricity consumption is imported from Israel at high prices. Also, petroleum products are purchased from Israel.	• Average prices of energy: LPG (5.66 NIS/kg), Kerosene (6.42 NIS/L), Coal (6.92 NIS/kg), Gasoline (6.89 NIS/L). Diesel (6.42 NIS/L), Oils and Lubricants (14.66 NIS/kg). • Quantity of electricity purchases (MWh) in the West Bank is 3,401,247.

After harvesting and collecting of raw olives, the production of olive oil starts in fully-automatic and semi automatic local olive oil pressers which produced 100% natural olive oil without any artificial additives or pigments. According to the PCBS 2012 statistics, there are 258 operating olive presses in West Bank, with a pressing capacity of 95,216 tons of olive from which 21,367 tons of extracted olive oil is produced. Given that the density of olive oil is 850 kg/m^3, the 2012's extracted quantities of olive oil are equivalent to 25,137,647 liters. Assuming that 75% (based on estimates of presser's owners) of these quantities are stored in (16 L) containers, the required number of containers is 1,178,327 containers. After pressing, olive oil is stored in either tin containers or plastic containers. Most of the exported oil is stored in tin containers. These are the main two packaging materials of olive oil. This research focuses on conducting an LCA study, within some certain limitations on these two packaging systems of Palestinian olive oil. The study aims at conducting a comprehensive comparison among these two packaging systems across their life cycles. Environmental impacts included in this study are selected and prioritized in accordance to their importance in the Palestinian environmental context.

5.0 Methodology

LCA methodology consists of four phases, each having its important role in the study. They are interrelated throughout the entire assessment in accordance with the current terminology of the ISO standards (ISO 14040, ISO 14041, ISO14042, and ISO 14043). These phases are goal and scope definition, inventory analysis, impact assessment, and interpretation, as shown in Figure (1). The following sections discuss the application of the four phases of LCA, based on ISO 14041-14043 series, as well the analysis for tin and plastic containers of olive oil.

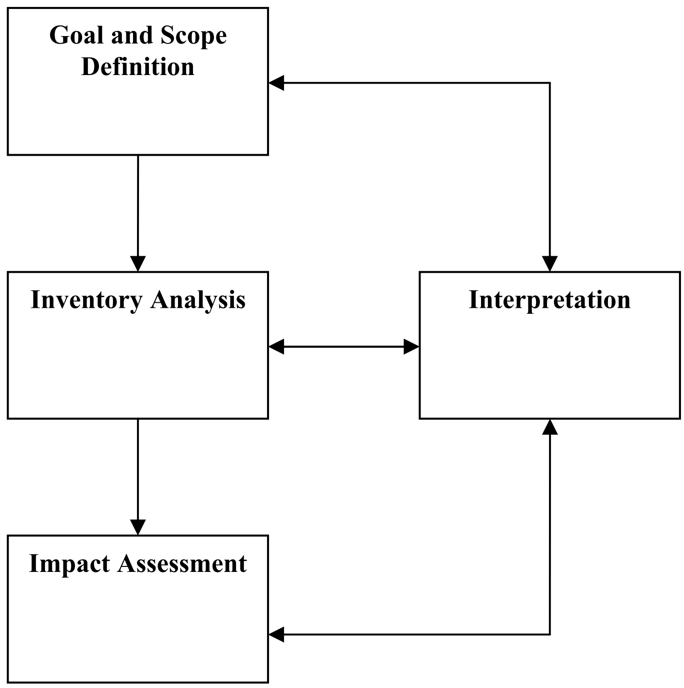

Figure (1): The main phases of LCA.

5.1 Goal and Scope Definition

The goal of this LCA study is to comprehensively compare between these two packaging systems across the life cycle of each one starting from upstream manufacturing process and ending with the downstream disposal of the package. The scope of this study is limited to the main two packaging systems which are plastic and tin containers of olive oil in Palestine. The comparison between the two systems will be from an environmental perspective. To facilitate comparison, the selected functional unit can be expressed in terms of any volume of olive oil contained in each container. The functional unit of 1000 L of olive oil was adopted in this study.

The LCA will be based on the system boundary of the two packaging systems starting from the manufacturing of the packaging materials, filling with oil, using, and ending with recycling and disposal. The system boundary excludes the following stages: transportation, raw materials extraction and processing, tertiary packaging and emissions, due to the unavailability of their data as well as the difficulty in estimating them. However, the exclusion of these items will affect the results of the LCA. More specifically, if the data related to the excluded data could be obtained or estimated; decisions about the outperformance of one packaging system over the other might be changed. Eventually, upon availability of these missing data will result in a more holistic LCA and hence will lead to more realistic results. The author recommends such an expansion a future research issue for him and/or other interested researchers.

5.2 Life Cycle Inventory (LCI) Analysis

Data was collected from the production sites of local industries associated with the unit processes within the system boundaries. Some data was collected from published sources. More specifically, recent statistics relevant to this study were obtained from PCBS as well as from Occupational Safety and Health Administration (OSHA) Standards. Data categories are: energy, raw materials (resin of plastic containers, tin, dyes of plastic containers and welding wires of tin containers), products and ancillary products (caps), solid waste and noise. Data quality requirements included time coverage of two years and a geographical coverage in local market (Nablus city). LCI analysis is concerned with data collection and calculation procedures. Table (2) summarizes all input and output data for the life cycle of the plastic packaging system. This data was obtained from the historical records available in the Nablus Canning Industries Factory. The quantities for each input and output were calculated and estimated with respect to the functional unit (1000 L) of olive oil. The quantities are presented in International System (SI) of units. On the other hand, the tin packaging system's relevant data are summarized in Table (3).

5.3 Life Cycle Impact Assessment (LCIA)

This section describes and includes which impact categories are relevant to the system. The main aim was not to include all the impact categories related to the system, but to include these which are needed and available for data relating to them. Five impact categories were considered to study and are adopted in comparison according to ISO. These impact categories included abiotic resources (energy and water), solid waste, human toxicity and health (dust) and others (noise), as illustrated in Table (4).

Table (2): A summary of life cycle environmental burdens of plastic containers per 1000 L of olive oil.

Plastic Containers		
Input		
Materials	**Unit**	**Quantity**
Raw materials (resin of high density poly ethylene)	kg	64.7208
Nylons (secondary packaging)	kg	1.0125
Water consumption	L	1.3438
Energy(electricity)	MJ	110.396
Output		
Good containers	kg	46.2492
Defective containers (recyclable)	kg	0.9708
Solid wastes (recyclable)	kg	17.5
Waste water	L	1.3438
Waste nylon	kg	1.0125
Human toxicity and health (Dust)	kg	3.0785
Noise	dBA	92

Table (3): A summary of life cycle environmental burdens of tin containers per 1000 L of olive oil.

Tin Containers		
Input		
Materials	**Unit**	**Quantity**
Raw materials (tin sheets)	Kg	69.0075
Nylons (secondary packaging)	Kg	0.025
Welding wires	Kg	0.3125
Rubber	Kg	0.3125
Water consumption	L	1.8563
Energy(electricity)	MJ	18.54
Energy(diesel)	MJ	33.93
Output		
Good containers	Kg	67.5937
Defective containers (scrap)	Kg	0.3450
Solid wastes (scrap)	Kg	1.4125
Solid wastes-welding wires (sold)	Kg	0.2813
Waste water	L	1.8563
Waste nylon	Kg	0.025
Human toxicity and health (emissions)	Kg	Not Available
Noise	dBA	96

Table (4): Impact categories of the study.

Environmental Impact	Description
Abiotic Resources (Water)	Water is considered as one of the most important and sensitive issues in the middle east, where increasing water quality deterioration is obvious. Water resources are very limited and not adequate to satisfy water demands. Palestinians suffer a lot from water deficiencies in Palestine and they do not have the full control on their water resources as they are deprived from legal water rights. Thus, water is given a high priority in the LCIA of this study.
Abiotic Resources (Energy)	Energy inputs to any production system may come from various resources including electricity, fuel and others. Electricity and diesel consumptions are considered in the LCIA of this study.
Land Use (Solid Waste)	Solid wastes are very important in the Palestinian environmental context as they are considered a main source of pollution. Nevertheless, solid wastes could form natural resources if they are properly managed and treated.
Human Toxicity and Health	This includes emissions to air including dust, emissions to water such as acids, emissions to land such as mineral wastes.
Others	Under this category, industrial noise is considered. In plastic packaging system, noise is generated from crushing machines as well as from plastic production line. Noise in tin packaging system is measured when all machines are on. Industrial noise exposure time periods are assumed to be the same under both packaging systems

After selecting the impact categories, the LCIA results are used to classify and correlate the results to the adopted impact categories as illustrated in Table (5).

Table (5): Classification of LCIA results to impact categories.

Impact Category / LCIA Result	Abiotic resources	Land Use	Human Toxicity & Health	Others
Energy	X			
Water	X			
Solid Wastes		X		
Dust		X	X	
Noise				X

The next step in the analysis is the calculation of category indicator results (characterization). This involves the conversion of the LCIA results to common units and the aggregation of the converted results within the impact category. This conversion uses characterization factors.

Table (6) summarizes the numerical indicator results for each packaging system.

Table (6): Characterized impact categories per functional unit (1000 L).

	Impact Categories	Unit	Plastic Containers	Tin Containers
Abiotic Resources	**Energy**	MJ	110.396	52.47
	Water	L	1.3438	1.8563
Solid Waste	**Recyclable solid waste**	Kg	18.425	0.2813 (sold)
	Disposed solid waste	Kg	4.091	1.7825
Human Toxicity and Health	**Dust**	Kg	3.0785	Not applicable
Others	**Noise**	dBA	92	96

The characterized data are normalized to better understand the relative magnitude for each indicator's results of the product system under study (ISO 14042: 2000). The aim of normalization is to better understand the order of magnitude for each indicator of a system under study. In this study, it was found helpful to express the contribution of the functional unit to each impact category relative to per Palestinian capita level considering the latest estimate available of Palestinian population in West Bank which is 2,719,112 capita (Source: PCBS, 2013).

Within normalization, all LCI and LCIA results of the functional unit are expressed as fractions of a well-defined reference contribution of a given community over a given period of time. In ISO 2000, the normalization step is considered as an optional element of LCIA (ISO, 2000 cited in Grant *et al.,* 2001). Table (7) summarizes the value of the considered categories per Palestinian capita under both packaging systems.

Within the Palestinian context, weights on a scale from 1 to 10 are assigned to each impact category as summarized in Table (8). Weight selection is based on value-choices and is not based on natural science. Different individuals, organizations and societies may have different preferences. Therefore, it is possible that different parties will obtain different weighting results based on the same indicator results or normalized indicator results (ISO, 2000).

There are many algorithms in the literature for optimizing the weights in LCIA. The reader can refer to Adedeji (2006), Rowley and Peters (2009), and Komly (2011) for more details of the various algorithms used in LCA-weights optimization. Since optimizing weights in LCIA is beyond the core scope of this study, the weights are selected based on their importance in the Palestinian environmental context as recommended by people specialized in conducting environmental studies in Palestine.

Table (7): Statistical information of considered impact categories in Palestine.

	Impact Categories	Unit	Total Annual Impact in Palestine	Fraction of the Two Packaging Systems from Total	Annual Impact per Palestinian Capita(*)
Abiotic Resources	**Energy**	MJ	2004 millions	$8.1265*10^{-8}$	733
	Water	L	270,000 millions	$1.1852*10^{-11}$	99,297.12
Solid Waste	**Solid Wastes**	Kg	872.298 millions	$2.818*10^{-8}$	320.80
Human Toxicity and Health	**Dust**	Kg	Not Available	Not Applicable	Not Available
Others	**Noise**	dBA	Based OSHA Standards		

(*): Palestinian population in West Bank is 2,719,112 capita (Source: PCBS, 2013).

Table (8): Weights assigned to selected impact categories.

Impact Category	Water	Energy	Solid Wastes	Human Toxicity and Health	Noise	Sum of Weights
Weight	10	9	6	3	3	**31**
Relative Weight (%)	32.2(*)	29	19.4	9.7	9.7	**100**

(*) 32.2 =(10/31)X100%

The adopted impact categories were arranged according to their importance to Palestinians. Accordingly, Table (9) presents the relative weighted values of the impact categories for each packaging system. As shown in Table (9), it is obvious that tin containers outperform plastic containers as they have lower score of environmental impact compared to plastic ones.

5.4 Interpretation

In this section, tin and plastic containers are compared for each individual impact category adopted in this study based on the tabulated results in Table (9). Starting with water consumption, the results reveal that tin containers consume more water over their life cycles compared to plastic ones. With respect to energy consumption, tin containers consume less energy compared to the consumption of plastic containers. The total weighted values of solid wastes (both disposed and recycled) generated by plastic containers are greater than those generated by tin containers. Also, plastic containers generate more dust than tin containers. However, tin containers produce more industrial noise than plastic ones.

Table (9): Weighted values of impact categories of both packaging systems.

	Impact Categories	**Unit**	**Relative Weight**	**Plastic Packaging System**		**Tin Packaging System**	
				Raw Values	**Weighted Values**	**Raw Values**	**Weighted Values**
Abiotic Resources	**Water**	L	0.322	1.3438	0.4327	1.8563	0.5977
	Energy	MJ	0.29	110.396	32.0148	52.47	15.2163
Solid Waste	**Disposed**	Kg	0.194	4.091	0.7937	1.7825	0.3458
	Recycled	Kg	0.194	18.425	3.4920	0.2813 (sold)	0.0546
Human Toxicity and Health	**Dust**	Kg	0.097	3.0785	0.2986	0	0.0000
Others	**Noise**	dBA	0.097	92	8.9240	96	9.3120
Total Weighted Score (dimensionless)				**49.9558**		**25.5264**	

5.5 Sensitivity Analysis

As discussed in the previous section, the environmental superiority of one packaging system over the other highly depends on the compared quantities as well as on the assigned weights. One can assign different weights than those adopted in this study to come up with different numbers of the total weighted scores. The weighted values of Table (9) reveal that energy consumption is a high contributor (64% in plastic and 60% in tin) to the environmental impact, among other ones, to the total weighted scores under both packaging systems. However, energy consumption under plastic system is almost twice that under tin system. Likewise, solid waste generation under plastic system is approximately eleven times than under tin system. Consequently, to make the usage of plastic containers attracting as tin ones, either energy consumption or solid wastes generation should be considered for reduction. Reduction in energy might be accomplished via using alternative plastic raw materials (polymers) which consume lower energy in production less than the current used raw materials. On the other hand, generated solid wastes could be reduced through adopting a process quality improvement programs aiming at reducing the rates of wastes, and hence the quantities, produced in the current plastic production processes.

6.0 Conclusions and Recommendations

In this LCA study, the main two packaging systems used for storing olive oil in Palestine were compared. These systems are the plastic containers and the tin containers. The study started with collecting data from a local factory which produces the plastic and tin containers. Five environmental impact categories are identified and considered in this study. Those categories include water, energy, solid waste, human toxicity and health (dust) and noise. Each impact category was assigned a weight based on their importance in the Palestinian context. For each packaging system, the total score was computed and the results revealed system. This means that the tin packaging system has a lower environmental impact than the plastic packaging system. Considering each impact separately, it was found that tin containers' production consumes more water over their entire life cycle compared to plastic containers. However, plastic containers’ production consumes more energy in their production compared to tin containers. Plastic containers production generates more solid wastes than tin packages. However, when it comes to plastic, cycling is possible, while tin wastes are usually disposed. Producing tin packages does not produce dust while plastic produces dust. Noise in tin production is higher than plastic production.

Based on the above concluding remarks and within the limitations of this study, the adoption of tin containers, as packaging materials for olive oil in Palestine, is recommended since they have lower environmental adverse impacts compared to plastic containers. Also, it is strongly recommended to expand the system boundary of this study to include raw material extraction, raw material processing and transportation in order to have a more comprehensive and realistic comparison between tin and plastic containers.

References

- Adedeji, A. (2006). *Optimum Design of An Expanded Cumulative Energy Consumption in a Strawable-Walled Building*. Nigerian Journal of Construction Technology and Management, Vol. 7, No.1, 146-156.
- Avadi, A. & Freon, P. (2013). *Review Life cycle assessment of fisheries: A review for fisheries scientists and managers*. Fisheries Research. 143: 21-38.
- Bengtsson, J. & Seddon, J. (2013). *Cradle to retailer or quick service restaurant gate life cycle assessment of chicken products in Australia*. Journal of Cleaner Production. 41: 291-300.
- Grant, T. James, K. Lundie, S, & Sonneveld, K. (2001). *Stage 2 Report for Life Cycle Assessment for Paper and Packaging Waste Management Scenarios in Victoria*. Stage 2 of the National Project on Life Cycle Assessment of Waste Management Systems for Domestic Paper and Packaging. Melbourne, Australia.

- Hakala, S. Virtanen, Y. Meinander, K. & Tanner, T. (1997). *Life Cycle Assessment: Comparison of Bipolymer and Traditional Diaper Systems*. VTT Tiedotteita, Technical Research Center of Finland, 1876: 1-92.
- Harun, K., Bateman, R., & Cheng K., 2010. Modeling and Characterization of Automotive Coating Systems for Sustainable Manufacturing. *Proceedings of the 8th International Conference on Manufacturing Research ICMR 2010*, 3-4.
- International Organization for Standardization (ISO). (1997). Principles and Framework of Life Cycle Assessment (ISO 14040). Geneva, Switzerland.
- International Organization for Standardization (ISO). (1998). Goal and Scope Definition: Inventory Analysis (ISO 14041). Geneva, Switzerland.
- International Organization for Standardization (ISO). (2000). Life Cycle Impact Assessment: Draft International Standard (ISO 14042). Geneva, Switzerland.
- International Organization for Standardization (ISO). (2000). Life Cycle Interpretation: Draft International Standard (14043). Geneva, Switzerland.
- Jensen, A. Hoffman, L. Moller, B. Schmidt, A. Christiansen, K. & Elkington, J. (1997). *Life Cycle Assessment: A Guide to Approaches, Experiences, and Information Sources*. Environmental Issues Series, No. 6, European Environmental Agency.
- Claude Emma Komly, C.E. Azzaro-Pantel, C. Hubert, A. & Archambault, V. (2011). *Multicriteria optimization strategy of waste management system based on a parametrizable Life Cycle Assessment approach*. Ecotech & tools Conference – 30th nov. to 2nd Dec, France.
- Mangena, S.J. Brent, A.C. (2006). *Application of a Life Cycle Impact Assessment framework to evaluate and compare environmental*

performances with economic values of supplied coal products. Journal of Cleaner Production. 14:1071-1084.

- Mata, M. & Costa, A. (2001). *Life Cycle Assessment of Different Reuse Percentages for Glass Beer Bottles*. International Journal of Life Cycle Assessment, 6 (5): 307-319..
- Palestinian Central Bureau of Statistics (PCBS). (2013). *Statistics and Publications*. Available from: http://www.pcbs.gov.ps.
- Rowley, H.V. & Peters, G.M. (2009). *Multi-Criteria Methods for the Aggregation of Life Cycle Impacts*, in 6thAustralian Conference on Life Cycle Assessment, Melbourne, Australia.
- Saleh, Y. (2003). *Life Cycle Assessment of Packaging Materials of Carbonated Soft Drinks in Jordan*. Master Thesis. University of Jordan, Amman, Jordan.
- Shaheen, L. (2013). *Rapid Urbanization and the Challenge of Sustainable Urban Development in Palestinian Cities*. World Academy of Science, Engineering and Technology 75.
- Xie, M. Li, L. Qiao, Qi. Sun, Q. Sun, T. (2011). *A comparative study on milk packaging using life cycle assessment: from PA-PE-Al laminate and polyethylene in China*. Journal of Cleaner Production. 19: 2100-2106.
- Yasuoka, H. (2002). *Life Cycle Assessment of PET Bottle Including Open-Loop Recycling*. Memoirs of the Faculty of Engineering, Kobe University, Japan, 44: 139-149.
- Zhou, J. Chang, V.W.C. & Fane, A. G. (2013). *An improved life cycle impact assessment (LCIA) approach for assessing aquatic eco-toxic impact of brine disposal from seawater desalination plants*. Desalination. 308: 233-241.