THE ECOLOGICAL PROFILE OF COCOA, CHOCOLATE, AND SUGAR CONFECTIONERIES IN AZERBAIJAN

Sevinj Hajiyeva, Maltam Shamilova-Jalilova*

Faculty of Ecology and Soil Science, Baku State University, Baku, Azerbaijan

Abstract. This study evaluates the life cycle environmental impacts of cocoa, chocolate, and sugar confectioneries in Azerbaijan between 2014-2020 years. The study was conducted based on the statistical results of "Food Balance of Azerbaijan" according to cocoa, chocolate, and confectionery products for 2014-2020. To perform LCA was used the ISO 14040-14044 series in the international ISO procedural framework.

The results obtained under the three damage models in Eco- indicator'99, human health is based on carcinogens, respiratory organics, respiratory inorganics, climate change, radiation, ozone layer depletion midpoints, ecosystem quality is based on land use, acidification/ eutrophication, ecotoxicity, and resources are based on minerals, fossil fuels.

The dependence of quantitative indicators associated with all midpoints has been calculated in produced, consumed as food products and total of utilization of cocoa, chocolate and confectioneries between 2014-2020 years within sequence 2015 < 2014 < 2016 < 2017 < 2018 < 2019, 2016 < 2017 < 2015 < 2014 < 2018 < 2019 < 2020 and 2016 < 2015 = 2017 < 2018 < 2014 < 2019 < 2020, respectively. Only, the characteristic of land use and minerals were distinguished in consumed as food products, and expressed as 2016≤2017<2015<2014<2018<2019<2020 and 2016<2015=2017<2014<2018<2019 <2020, accordingly.

As for the noticeable values of all midpoints, the quantitative indicators of carcinogens, climate change, respiratory inorganic substances, and fossil fuels are consistently increasing. This regularity is reflected in the percentage indicators of endpoints, and the highest share is resources, it was followed by human health and ecosystem quality.

Keywords: *LCA, midpoints, endpoints, Eco-indicator 99, SimoPro software.*

Corresponding Author: *Maltam Shamilova-Jalilova, Faculty of Ecology and Soil Science, Baku State University, AZ 1148, Baku, Azerbaijan, Tel.: +994516978709, e-mail: meltemshamilova@gmail.com*

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1. Introduction

LCA is a tool for assessing the impact on the environment of a product or process throughout its life cycle, from cultivation to processing, use, and disposal of wastes associated with its final end-use. This identifies and quantifies energy and materials used and wastes released to the environment, computes their environmental impact, interprets results, and evaluate improvement opportunities (Narayanaswamy *et al.*, 2002, Demirer, 2017). Environmental impacts in the LCA context are collected as adverse impacts on ecosystem quality, human health, and natural resources. ISO 14040 is a general standard covering four phases - goal and scope definition, life cycle inventory analysis, life cycle impact assessment, life cycle interpretation in an LCA (Lee & Inaba, 2004, ISO 14040, 1997). Its supplementing are ISO 14041 which deals with goal and scope definition and life cycle inventory methods (ISO 14041, 1998), ISO 14042 refers to life cycle impact assessment methods (ISO 14042, 2000) and ISO 14043 explains life cycle interpretation methods (ISO 14043, 2000). Life cycle impact categories are resource energy use, global warming, human toxicity, atmospheric acidification, terrestrial ecotoxicity, aquatic eutrophication, dryland salinity (land use impact), and loss of biodiversity (land use impact) (Narayanaswamy *et al.*, 2002, Miah *et al.*, 2018, Jekayinfa *et al.*, 2013).

Depending on the stage of the life cycle, it could be grouped as “cradle to grave”, “cradle to gate”, “cradle to cradle”, and “gate to gate”. If analyze is covering all life cycles of a product or process it is defined as “cradle to grave”. A “cradle-to-gate” is covered by a product or process from raw material acquisition (“cradle”) to the stage where it is delivered to the factory (“gate”). The “cradle-to-cradle” approach toward the recycling of waste during the waste disposal stage. If it refers to an approach that considers the life cycle of a stage of a product or process, it is identified as “gate-to-gate” (Demirer, 2017, Jiménez-González *et al.*, 2000). Due to the measurement of environmental impacts, there is the available functional unit used to compare different physical products delivering the same functionality (Narayanaswamy *et al.*, 2002, Demirer, 2017).

Due to the diversity of confectionery products, there are complex supply chains, ingredients that are grown in specific regions of the world. Specialized equipment to process and transform ingredients, various scientific formulation to create nutritious and tasty recipes, and retailers contribute the environmental sustainability and requires a systematic approach to analyze and improve the confectionery sector across the full supply chain from raw materials to manufacturing to consumption and disposal (Jekayinfa *et al*., 2013). According to AZS 839-2015 (CODEX STAN 87-1981) adopted by the Board of the State Committee for Standardization and Metrology and Patents, flour, starch, and other food products can be added to the preparation of various chocolate products. These additives should not exceed 40% of the total mass of the product. Due to composition, chocolate types are Chocolate, Sweet chocolate, Couverture chocolate, Milk chocolate, Family milk chocolate, Milk chocolate couverture and also other chocolate products, like White chocolate, Gianduja chocolate, Gianduja milk chocolate, Chocolate para mesa. Due to forms of chocolate types, it is divided to Chocolate vermicelli and Chocolate flakes, Filled chocolate, A Chocolate or Praline (Standard For Chocolate And Chocolate Products CODEX STAN 87 – 1981). The supplies and use of processed products in absolute quantities were described in the statistical yearbook «Food balances of Azerbaijan» which contains data for the 2014-2020 years (State Statistical Committee of The Republic of Azerbaijan Official publication, 2021). The useful statistical values of cocoa, chocolate, and sugar confectioneries between the 2014-2020 years were listed in Table 1 and Table 2.

According to current studies, the environmental impacts of several types of confectionery products are carried out by Life Cycle Assessment (LCA) which integrates itself with an advanced systems analysis tool (Recanati *et al.*, 2018, Nilsson *et al.*, 2011). According to Recanati et al. (2018), based on 1 kg functional unit of dark chocolate during cradle-to-grave global warming potential, eutrophication potential, ozone layer depletion potential, acidification potential, abiotic depletion, cumulative energy demand, photochemical ozone creation potential is collected as environmental impact category. Vesce et al. (2016) suppose that in the same functional unit of chocolate during gate-to-gate human health, ecosystem quality, climate change, and resources are assembled as impacts (Vesce *et al.*, 2016). Büsser and Jungbluth (2009) measured LCA for 1 kg of chocolate according to cradle-to-grave and calculated cumulative energy demand (CED) nonrenewable, global warming potential (GWP), ozone layer depletion, acidification, and eutrophication. Sugar within 125 g of foam sweets and 2 kg of jelly sweets, during cradle-to-gate, the global warming potential (GWP), eutrophication, and primary energy are impacts on LCA estimation (Nilsson *et al.*, 2011). An example for fine bakery ware, 1 kg of packaged cupcake within the same life cycle strategy, the primary energy demand (PED), global warming potential (GWP), and water footprint are defined as impacts (Konstantas *et al.*, 2017b).

Table 1. Resources and utilization of cocoa, chocolate, and sugar confectioneries, ton (State Statistical Committee of The Republic of Azerbaijan Official publication, 2021)

Years	Stocks at the beginning of the year	Production	Import	Total of resources	For fodder of cattle and Poultries	Consumed as food products	Export	Losses	Stocks at the end of the year	Total of utilization
2020	21790	11275	27264	60329	154	33794	1835	384	24162	60329
2019	19 416	9 677	25 313	54 406	139	29 612	2 520	345	21 790	54 406
2018	17250	7553	23675	48478	124	26905	1725	308	19416	48478
2017	16374	7064	19632	43070	110	22592	2845	273	17250	43070
2016	17253	6556	17075	40884	104	22086	2059	261	16374	40884
2015	19960	3633	19484	43077	110	22755	2685	274	17253	43077
2014	20394	4505	24942	49841	127	25437	4000	317	19960	49841

Table 2. Level of self-sufficiency of basic industrial processed and Consumption of main industrial processes (State Statistical Committee of The Republic of Azerbaijan Official publication, 2021)

	2014	2015	2016	2017	2018	2019	2020
Level of self-sufficiency of basic industrial processed cocoa, chocolate and sugar confectioneries -food products, percent	17,7	17,8	30,4	29,6	25,6	29,8	30,7
Consumption of main industrial processed cocoa, chocolate and sugar confectioneries food products per capita, annual kilogram	2,7	2,4	2,3	2,3	2,7	3,0	3,4

As known, the produced chocolate is packed in aluminum foil and paper, transported from the retailers to the household. So far, there has been a study, which is based on calculating environmental indicators. These indicators are cumulative energy demand (CED), non-renewable, global warming, ozone layer depletion (ODP), acidification and eutrophication of dark, milk, and white chocolate and chocolate with sultanas. Whole supply chain of compositions and as conclusion all cases the production of chocolate is the most contributing phase in the life cycle. The most relevant measures to reduce environmental impacts for the production and supply chain would be improvements in the agricultural production of cocoa beans and milk (Büsser & Jungbluth, 2009).

Miah et al., (2018) studied the environmental life cycle analysis of sugar confectionery, milk chocolate, confectionery, dark chocolate confectionery, milk chocolate biscuit, confectionery, and milk-based confectionery at a confectionery factory in the UK. It was found that sugar confectionery had the lowest aggregated environmental impact compared to dark chocolate confectionery which had the highest, the environmental hotspots due to ingredients. (Miah *et al*., 2018). Other research was carried out by Antonios et al., (2018) and was chosen molded chocolate, chocolate countlines, and chocolates in bags, the raw materials; chocolate production process and packaging are hotspots across all impact categories for all three product types due to milk powder, cocoa derivatives, sugar, and palm oil. The improvement opportunities targeting the key contributing stages suggest that the GWP of chocolates could be reduced by 14%–19%. Chocolate countlines have the highest contribution to the total impacts at the UK level (37%–43%), followed by chocolates in bags (28%–33%). Molded chocolates and other chocolate confectionary make up the rest of the impact, with a roughly equal share each. Chocolate consumption in the UK contributes 4.7% to the primary energy consumption and 2.4% to the GHG emissions from the whole food and drink sector.

The current research paper considers a range of cocoa, chocolate, and sugar confectioneries products to evaluate the environmental impacts of production and consumption in Azerbaijan between the 2014-2020 years. The evaluation was set according to Table 1 and Table 2 based on the gate-to-gate study. The next section provides details of estimation of the environmental consequences of cocoa, chocolate and sugar confectioneries production and consumption, and provides data knowledge about the LCA by an overview of the methodology used to evaluate the environmental impacts. According to the common literature approach of 1 kg of the product as a functional unit, consequently, all the allocations are performed in terms of mass.

2. Methodology

Life cycle assessment (LCA) was used to estimate the impacts of cocoa, chocolate and sugar confectioneries, following the ISO 14040/14044 guidelines (ISO, 2006a&b) (Konstantas A. *et al.,* 2018). The methodology, data, and assumptions are described in more detail in the following sections.

Goal and scope

The goal of the study is to assess the environmental impacts of the production and consumption of cocoa, chocolate, and sugar confectioneries products in Azerbaijan between the 2014-2020 years. The study considers Table 1 and Table 2 based on the gate-to-gate study. The current study of LCA has covered production, consumption as food products, and total utilization (State Statistical Committee of The Republic of Azerbaijan Official publication, 2021). Manufacturing is combined demand of electricity, steam, and water consumption, cleaning activities. The packaging is included primary -aluminum foil, secondary – corrugated boxes, and tertiary - stretch film. Distribution and consumption consist of storage in a regional distribution center and at a retailer, and consumption at home. Waste management relates to treatment and disposal of process and post-consumer waste. Transport is defined as the transport of raw materials and packaging to the production facility, product, and waste transport along the life cycle (Konstantas *et al*., 2018, Bianchi *et al*., 2021).

Life cycle inventory (LCI)

In the inventory analysis, data about cocoa, chocolate, and sugar confectioneries products are collected according to the statistical results of "Food Balance of Azerbaijan" in production, consumption as food products, and total utilization for 2014-2020 and are modeled through SimaPro 9.1.1.1 Analyst Demo software capabilities based on the gate-to-gate.

Life cycle impact assessment (LCIA)

LCIA is an important tool in any LCA study and there are several methods available to express quantitatively different life cycle impact indicators. To the point of Single Score Analysis, Eco-Indicator'99 is widely used to an environmental load of a product/process/service (Muthu, 2014). Due to the damages in environmental load, endpoints are categorized as human health, ecosystem quality, and resources (Muthu, 2014; Goedkoop *et al.*, 1998; Dreyer *et al.*, 2003).

The following impact indicators refer to one of the endpoints described earlier and the impact categories of the eco-indicator'99 methodology are collected within 11 midpoints: carcinogens, respiratory organics, respiratory inorganics, climate change, radiation, ozone layer depletion, ecotoxicity, acidification/eutrophication, land use, minerals, fossil fuels (Muthu, 2014, Goedkoop *et al.*, 2010).

The value of midpoints and endpoints are calculated and compared through the eco-indicator unit by MPt.

3. Results and discussion

As shown in Figure 1, all midpoints of cocoa, chocolate, and confectioneries produced were reached their lowest level in 2015 and their highest level in 2020. Generally, according to quantitative indicators of all midpoints have increased in the direction of 2015 < 2014 < 2016 < 2017 < 2018 < 2019 < 2020. Moreover, the noticeable values of all midpoints increase in sequence carcinogens, followed by climate change, respiratory inorganics, and fossil fuels (Figure 4).

In Figure 1, the regularity obtained in the quantitative assessment of midpoints for the production of cocoa, chocolate, and confectionery was not observed in the assessment of consumption as food products and total utilization (Figures 1, 2, 3).

So, according to the following midpoints - carcinogens, respiratory organics, respiratory inorganics, climate change, radiation, ozone layer depletion, ecotoxicity, acidification/eutrophication and fossil fuels, the quantitative dependence between mentioned years was as 2016<2017<2015<2014<2018<2019<2020 (Figure 2). A soft deviation from current dependence has been observed in the midpoints of land use and minerals and is expressed as follows: 2016≤2017<2015<2014<2018<2019<2020 and 2016<2015=2017<2014<2018<2019<2020 respectively (Figure 2). According to the indicated dependencies of the consumption as food products of cocoa, chocolate, and confectionery between 2014-2020 years was expressed that the lowest and highest eco-indicator units of the quantitative assessment of all midpoints were observed in 2014 and 2020, respectively.

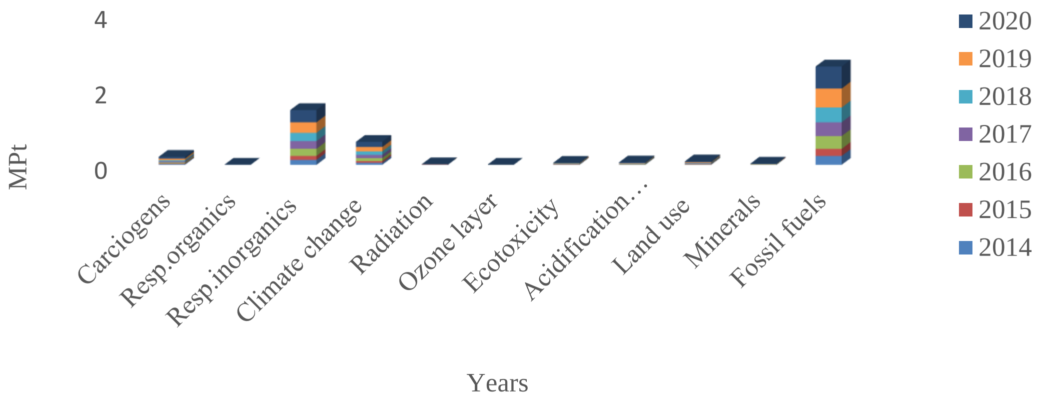

Figure 1. Evaluation of the midpoints of cocoa, chocolate, and confectioneries production in Azerbaijan between 2014-2020 years

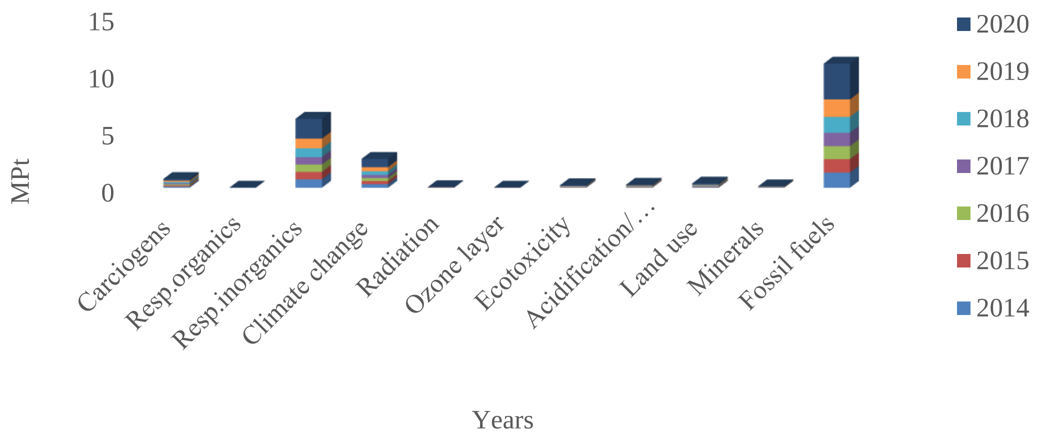

Figure 2. Evaluation of the midpoints of cocoa, chocolate, and confectioneries consumption as food products in Azerbaijan between the 2014-2020 years

In addition, a comparison of all midpoints eco-indicator units in the produced and consumed as food product of cocoa, chocolate, and confectioneries indicates that the noticeable values of all midpoints are the same as in production and increases carcinogens, climate change, respiratory inorganics, and fossil fuels in sequence (Figure 4).

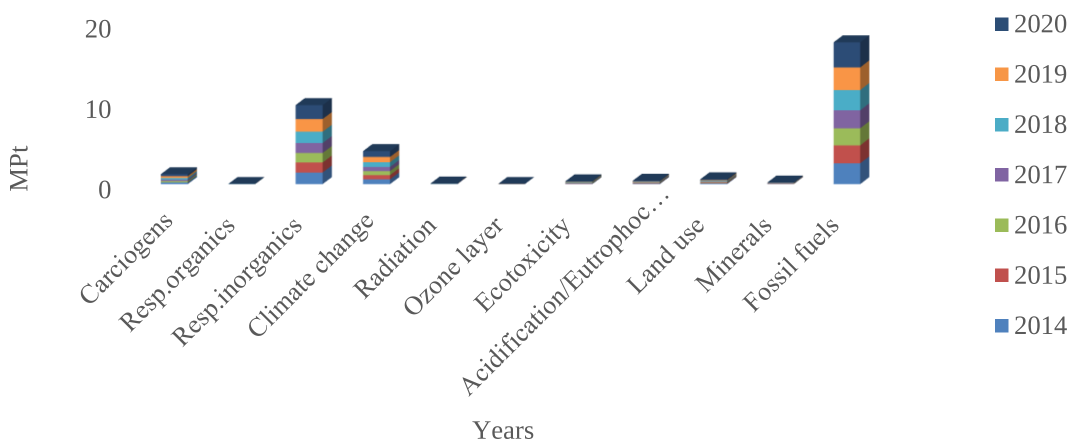

Figure 3. Evaluation of the midpoints of cocoa, chocolate, and confectioneries total utilization in Azerbaijan between 2014-2020 years

The quantitative dependence of all midpoints in the total utilization of cocoa, chocolate, and confectioneries between 2014-2020 years was observed as 2016<2015=2017<2018<2014<2019<2020 (Figure 3). The relationship between midpoints of the total utilization is the same as the production and consumption as food products in cocoa, chocolate, and confectioneries (Figure 4).

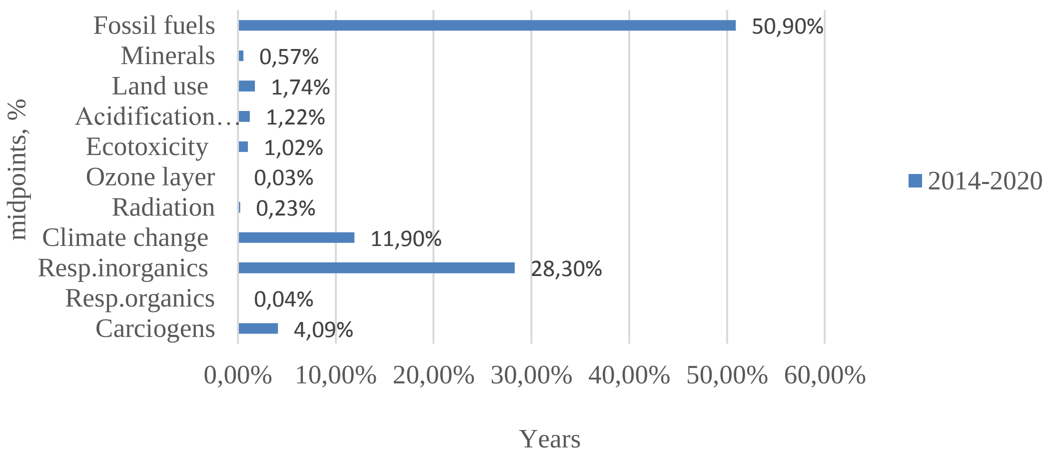

Figure 4. Evaluation by percent of the midpoints of production, consumption as food products, and total utilization of the cocoa, chocolate, and confectioneries in Azerbaijan between 2014-2020 years

Lee et al. (2004) were inventoried that theobromine with an anti-carcinogenic activity inhibits the suppression of GJIC (gap junctional intercellular communication), a pathological phenomenon occurring during the development of various kinds of cancers, thereby inhibiting the proliferation of cancer cells (Lee *et al.*, 2004). The antioxidant activity of cocoa flavanols is of particular interest for its potential influence on the initiation stage of carcinogenesis (Katz *et al.*, 2011). The environmental impacts associated with cocoa cultivation are related to the amount and type of inorganic fertilizers, pesticides, and insecticides used (Boakye-Yiadom *et al.*, 2021). Cocoa, chocolate, and confectioneries production harm the environment, which contributes to climate change by a net negative carbon footprint (Konstantas *et al.*, 2018, Reay, 2019). Packaging and manufacturing also influence the impacts, while transport has a significant contribution to ozone depletion, fossil fuel depletion, and the formation of photochemical oxidants (Konstantas *et al.*, 2018). The energy consumption structure of the confectionery plant is determined by the step of the production process, including caramel cooking, rolling, granulation, drying, and chilling (Wojdalski *et al.*, 2015). In Polish plants, the structure of energy consumption was as follows: heat from steam and hot water – 56.3%, fossil fuels – 36.3%, electricity –7.4% (Neryng *et al.*, 1999).

Midpoints are considered to be links in the cause-effect chain (an environmental mechanism) of an impact category, before the endpoints, at which characterization factors or indicators can be derived to reflect the relative importance of emissions or extractions (Bare, 2000). In the Eco- indicator'99 , human health damage is based on carcinogens, respiratory organics, respiratory inorganics, climate change, radiation, ozone layer depletion midpoints (Muthu, 2014). This is expressed a combination of the number of years lost and the number of years living in a disabled condition (Goedkoop *et al.*, 1999; 2010). The ecosystem quality is based on the land use, acidification/ eutrophication, ecotoxicity. It is expressed as the percentage of species that have become extinct in a given area during a certain period due to environmental load (Goedkoop *et al.*, 1999; 2010). The resources are based on the minerals, fossil fuels and is expressed in terms of the surplus energy needed for future extractions of minerals and fossil fuels (Goedkoop *et al.*, 2010). As mentioned in Figure 5, the endpoints of produced cocoa, chocolate, and confectioneries between the 2014-2020 years were described. A relative increase was observed in the linear dependence of resources (Figure 5). Human health and ecosystem quality of produced cocoa, chocolate, and confectioneries were at their lowest value in 2015, which explains the quantitative indicators of related midpoints in the mentioned year (Figure 1). According to both endpoints, their gradual dependence on quantitative indicators of them increased over the years (Figure 5).

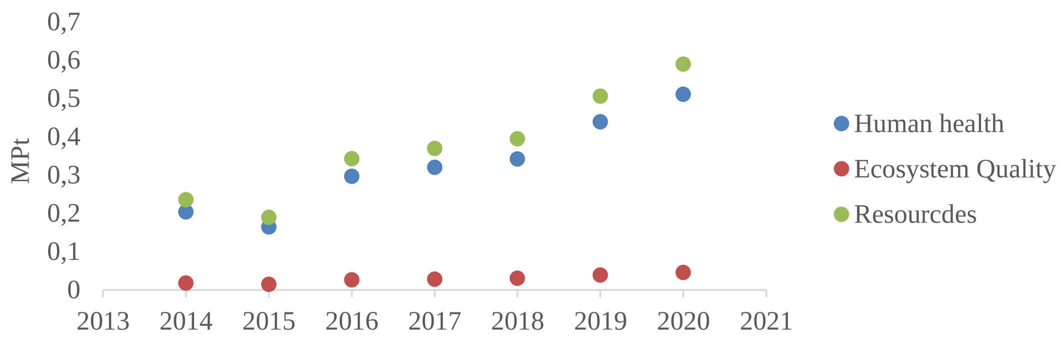

Figure 5. Evaluation of the endpoint of cocoa, chocolate, and confectioneries production in Azerbaijan between 2014-2020 years

Figures 6 and 7 are illustrated the assessment of the dependence of quantitative indicators of endpoints consumption as food products and total utilization of cocoa, chocolate, and confectioneries between 2014-2020 years. The dependences on resources during years show stability in previous years for both descriptions and reached their maximum values in 2020 (Figure 6 and 7). The main differences were observed in the dependence of human health and ecosystem quality and due to the quantitative indicator of midpoints through the years (Fig. 2 and 3).

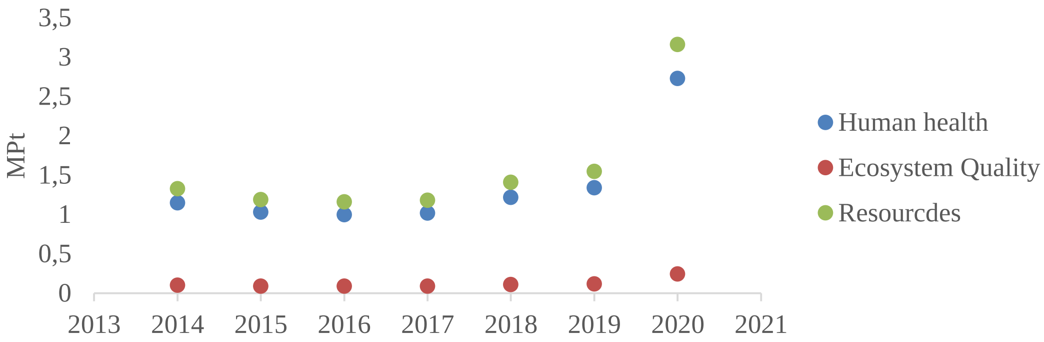

Figure 6. Evaluation of the endpoint of cocoa, chocolate, and confectioneries consumption as food products in Azerbaijan between 2014-2020 years

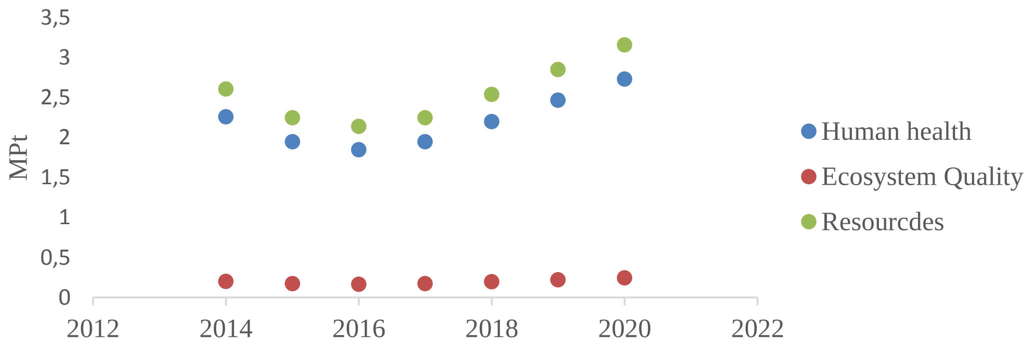

Figure 7. Evaluation of the endpoint of cocoa, chocolate, and confectioneries total utilization in Azerbaijan between 2014-2020

According to the percentage description of endpoints, ecosystem quality was in its 3.97 % value, followed by human health with 44.60% and resources with 51.50 %, respectively.

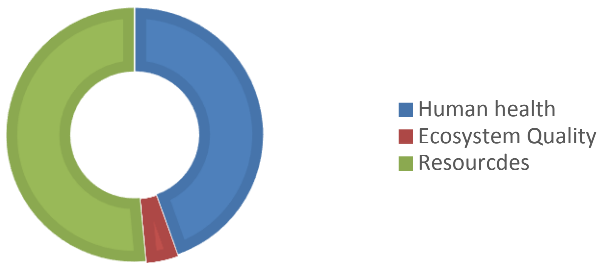

Figure 8. Evaluation by percent of the endpoints of production, consumption as food products, and total utilization of the cocoa, chocolate, and confectioneries in Azerbaijan between 2014-2020 years

4. Conclusion

An environmental life cycle analysis of cocoa, chocolate, and confectioneries in Azerbaijan between 2014-2020 years has been presented. Overall evaluation was carried out according to statistical values of production, consumption as food products, and total utilization of cocoa, chocolate, and confectioneries. Software analysis was based on quantitative indicators of midpoints and endpoints of Eco-indicators.

The 11 midpoints and 3 endpoints were described on the current research paper. The dependence of quantitative indicators associated with all midpoints has been calculated in produced, consumed as food products and total of utilization of cocoa, chocolate between and confectioneries 2014-2020 years and were observed as 2015 < 2014 < 2016 < 2017 < 2018 < 2019, 2016 < 2017 < 2015 < 2014 < 2018 < 2019 < 2020 and 2016 < 2015 = 2017 < 2018 < 2014 < 2019 < 2020, respectively. Only, the characteristic of land use and minerals were distinguished in consumed as food products, and expressed as 2016≤2017<2015<2014<2018<2019<2020 and 2016<2015=2017<2014<2018<2019<2020, accordingly.

The noticeable values of all midpoints are carcinogens, climate change, respiratory inorganics, and fossil fuels which increase in sequence.

In addition, as an endpoint, resources were stable with gradually increasing since 2016 and reaching the maximum value in 2020. Human health and ecosystem quality have been differentiated and explained by the value eco-indicator units of midpoints. Moreover, the percentage value of resources was expressed within the high indicator, and the lowest was ecosystem quality.

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