ISSN: 2414-1895 DOI: 10.6919/ICJE.202312_9(12).0046

Life Cycle Carbon Footprint Analysis of Pu 'er Organic Green Tea

Yingmei Li[1], Xiaoyan Shang[1,*], Zhaojie Luo[2], Li Ma[3], Xuchun Zhao[1]

[1] School of Biology and chemistry,Pu`er University, Pu`er 665000, Yunnan, China

[2] Pu'er Pulan Environmental Consulting Co., Ltd.,Pu 'er 665000, Yunnan, China

[3] Pu 'er Ethnic Middle School, Pu 'er 665000, Yunnan, China

*Corresponding author: 1121853433@qq.com

Abstract

In order to deeply study the life cycle carbon footprint emission of Pu 'er organic green tea, and understand the production technology and carbon emission intensity of Pu 'er organic green tea, this paper takes the life cycle carbon footprint of Pu 'er organic green tea as the research object, and divides the life cycle of Pu 'er organic green tea into five stages: raw material acquisition, manufacturing, distribution and sales, consumer use and waste treatment, and evaluates and analyzes its carbon footprint. The results show that the total carbon footprint of 1 kg Pu 'er organic green tea is 7.68kg, and its carbon footprint content is mainly in the manufacturing and use stages, accounting for 45.57% and 30.07% respectively. Therefore, it is suggested that more clean energy should be used in the manufacturing and using stages of organic tea to reduce the carbon footprint.

Keywords

Organic Green Tea; Life Cycle Assessment; Carbon Footprint.

1. Introduction

With the development of Pu 'er tea brand, consumers have a clear understanding of the anti-oxidation and acid-base balance of Pu 'er tea, and more people start to drink Pu 'er tea and drive the surrounding people to drink Pu 'er tea. At the same time, with the continuous expansion of new tea and other related tea industries, the demand for Pu 'er tea continues to grow, which provides new opportunities for the construction of organic tea industry. As a unique tea variety in China, Pu 'er tea culture has a long history. In 2008, Pu 'er tea was approved by the former General Administration of Quality Supervision, Inspection and Quarantine to implement the geographical indication product protection [1] , thus, the production and sales scale of Pu 'er tea continued to develop and expand. At present, more than 80% of Pu 'er tea in the whole province is sold to all provinces, municipalities and autonomous regions in China and more than 30 countries and regions in the world, which has a high reputation and popularity among consumers [2] . Practicing the concept of ecological civilization and developing green industries are very important for the completion of the new development concept. As a representative industry in the green economy, Pu 'er organic tea still maintains great market and research enthusiasm. It is an important step to study the life cycle carbon footprint of Pu 'er organic green tea.

China's tea culture has a long history and a wide variety. According to the degree of fermentation, it can be divided into six basic teas; Green tea, white tea, black tea, black tea, yellow tea and green tea (oolong tea) [3] . Green tea accounts for the largest proportion, which has a strong history and culture and unique lipid-lowering effect. The soup is yellow-green, and the taste is fresh, mellow and refreshing. It is a kind of tea with the largest output in China.

Abroad, the research on organic tea mainly focuses on biology, economy and ecology. In biology, Rothenberg Dylan O'Neill et al. [4] studied the relationship between soil acidification and soil microbial community. Peik Lin Teoh et al. [5] made a comparative analysis of the effects of Taidi tea and organic tea on cancer cell lesions, and found that organic tea has high value. Economically, Tian Huawei et al. [6] investigated the consumption willingness of organic tea in emerging countries such as Bangladesh, and put forward some suggestions on the promotion of organic tea. Hang Thi Minh Bui et al. [7] studied and analyzed the factors influencing the transformation of Taiwan tea to organic tea management in some areas of Vietnam. In terms of ecology, Mahmoudi Hashem et al. [8] conducted an investigation on the role of organic agriculture in sustainable development combined with consumers' hobbies. Azapagic et al. [9] discussed the carbon footprint of tea production and consumption in Kenya. The carbon footprint of tea is 12kg CO2 eq per kilogram of dry tea. Tea consumption stage accounts for 85% of the impact. Farshad et al. [10] analyzed the whole life cycle of Iranian green tea production, and found that compared with other steps, the tea production stage is the main contributor to environmental pollutants (57%), and using natural gas instead of diesel oil in the tea processing stage can reduce the carbon emissions of tea life cycle.

Domestic research on organic tea mainly focuses on production and pest control. In terms of production, Zhu Yuangui and others [11] put forward relevant measures in the production of organic tea based on existing experience. Zhao Yugui et al. [12] conducted scientific treatment research on each step of planting Baiyun Chunhao organic tea to improve production efficiency. In terms of pest control of organic tea, Dong Zuxiang, Gan Weihua, Hou Jianrong, He Yunchun and others [13-16] put forward specific measures and applied for patents. In the aspect of ecological environment impact, Yu Hao [17] based on the research method of net carbon footprint, analyzed the present situation of tea industry development and green production in Leishan County, and discussed the problems and limiting factors in the green development of tea industry in Leishan County. Qiang Xu et al. [18] selected two functional units of five kinds of tea products to evaluate their carbon footprint and primary energy demand by life cycle assessment. Huayang Zhen [19] took Wuyishan, China as an example, and compared the environmental and economic benefits of organic tea garden with traditional tea garden. It was found that organic tea garden and organic tea garden had considerable economic benefits and less environmental impact. Ming-Bao He et al. [20] studied the carbon footprint and carbon-neutral path of green tea in China, and quantified the carbon footprint, emission reduction potential and carbon-neutral path of green tea in 16 major tea-producing areas in China (except Hainan and Taiwan Province) through life cycle assessment. The study found that Sichuan, Hubei and Yunnan provinces had the largest carbon emissions, with 6.79, 6.14 and 5.96 Mt CO2 eq respectively.

In the past, most researches on life cycle assessment, carbon footprint, etc. were focused on industrial products or products related to industrial products, and there were few reports on tea resources and carbon footprint of organic tea. Therefore, this study used carbon footprint accounting method to estimate the life cycle carbon emissions of Pu 'er organic green tea, which will greatly promote the production, operation and management of organic tea in Pu 'er city.

2. Materials and Methods

2.1 Data Sources

This paper takes an organic tea garden in Pu 'er City as an example, which is located in Pu 'er City, the birthplace of tea trees in the world and the origin of Pu 'er tea. Based on the principle of sustainable development, the tea garden is committed to building an ecological tea garden, with more than 2,000 acres of organic tea gardens. It is an early and large-scale key organic tea demonstration park in Yunnan, and also a representative of large-scale organic tea gardens in Pu 'er City.

According to field investigation and field investigation, the tea garden mainly produces white tea, black tea, yellow tea, green tea, Pu 'er tea and flavored tea. The annual output of tea is about 500 tons,

 Volume 9 Issue 12, 2023
DOI: 10.6919/ICJE.202312_9(12).0046

of which white tea accounts for 18%, black tea 25%, yellow tea 5%, green tea 25%, Pu 'er tea 25% and flavored tea 2%.

As an ecological organic tea garden, in the process of planting, natural green manure is used, and sheep manure and rapeseed oil are mainly used as raw materials for processing as tea garden fertilizer; Biological or physical methods are used to control pests and diseases, mainly by biological drugs, insect-sticking plates, artificial insect catching and biological control; Mainly based on natural farming, without using any chemical synthetic pesticides and fertilizers.

2.2 Calculation Method of Carbon Footprint

The calculation of this study refers to ISO 14067-1. Multiply all the activity data in raw materials, manufacturing and waste stages in the product life cycle with their corresponding carbon emission coefficients, and accumulate and sum them up to get the total carbon emission in its life cycle. The formula is as follows:

$$CF = \sum (Z_r \times EF_r) \quad (1)$$

Where: CF is the carbon footprint; Z r is the quantity or intensity data of a substance or activity; EF r is the carbon emission factor [21] .See Table 1 for carbon emission factors.

Table 1. Carbon emission coefficient of each stage

stage	project	Carbon emission coefficient
Raw material acquisition	Organic fertilizer	0.050
	Transport fuel	1.660
	polyethylene pipe	2.480
manufacture	power	0.532
	diesel	2.606
	liquid gas	0.504
	tissue	0.020
	aluminium foil	5.500
	plastic bag	1.340
	tin box	1.100
	carton	1.200
	hop-pocket	0.400
transport	transport	0.372
use	power	0.532
	tap water	0.296
Waste disposal	bury	0.022
	incinerate	0.037

2.3 Objectives and Scope

2.3.1 Functional Units

Taking 1kg green tea as a functional unit, the carbon footprint accounting method was used to evaluate the life cycle CO_2 emission of organic green tea per kg Pu 'er. The carbon footprint

DOI: 10.6919/ICJE.202312_9(12).0046

international standard PAS 2050-2011 was used to quantitatively analyze the life cycle CO 2 emission of Pu 'er organic green tea.

2.3.2 System Boundary

The whole life cycle of Pu 'er organic green tea is divided into five stages: raw material acquisition, manufacturing, distribution and sales, consumer use and disposal. It is a life cycle process from "cradle to grave" [22] , from the beginning of tea planting as life, to the end of consumers' storage or drinking tea, and then to the end of tea residue.

2.4 Input-output List Analysis

The inputs of organic tea in the production process mainly include organic fertilizer, electricity, diesel oil, liquefied gas and packaging, including woven bags, tissue paper, aluminum foil, plastics, tin cans, cartons and cloth bags. The list of inputs is shown in Table 2.

Table 2. List of Input in Pu 'er Organic Green Tea Production Process

Input factors	unit	numerical value
Organic fertilizer	medical history	5
power	kW h	5
diesel	L	0.3
liquid gas	medical history	0.2
tissue	medical history	0.05
aluminium foil	g	0.03
plastic	g	0.06
can	g	0.6
carton	g	0.5
hop-pocket	g	0.1

According to the input factors and input amount in Table 2, the carbon emissions of organic tea in each stage are calculated. As shown in Table 3, among the five technological stages of organic green tea, the CO2 emission in the manufacturing stage of organic green tea is 3.5kg, with the largest carbon emission, followed by 2.31kg in the use stage, 1.65kg in the raw material stage, 0.19kg in the transportation stage and 0.03kg in the waste stage. The CO2 emission is the highest in the manufacturing stage (45.57%), followed by the organic green tea use stage (30.07%), raw material stage (21.48%), transportation stage (2.47%) and waste stage (0.39%).

Table 3. List of Carbon Emissions from Pu 'er Organic Green Tea Production Process

	Raw material stage	manufacturing stage	Transport stage	Use stage	Abandonment stage
Carbon emission /kg	1.65	3.5	0.19	2.31	0.03
Percentage/%	21.48	45.57	2.47	30.07	0.39

3. Results and Analysis

Through field investigation, the data of raw material selection and consumption, energy consumption, manufacturing process stage and final waste emission were obtained, and the carbon footprint of Pu

ISSN: 2414-1895 DOI: 10.6919/ICJE.202312_9(12).0046

'er organic green tea in the whole life cycle was calculated by using the carbon footprint emission formula. The total carbon footprint of 1 kg organic green tea in its life cycle is 7.68kg.

3.1 Analysis of CO2 Emissions in Different Stages of Organic Tea.

According to data, in the whole life cycle of organic tea, the carbon emission in the manufacturing stage is the highest, mainly because the process from tea stir-frying to final packaging in the manufacturing stage is complicated and the input and consumption are large. The use of diesel oil and liquefied gas in the stir-frying process increases the CO2 emission, and the mechanical equipment used in the processing and packaging process consumes a lot of electricity. In addition, the manufacture and use of various packaging such as plastic bags, tin cans and cloth bags further increase the CO2 emission at this stage. The carbon emission in the waste stage is the lowest, mainly because the input in this stage is less, the consumption of energy and hydropower is less, and burial and incineration are two ways of waste treatment, and the carbon emission coefficient in this process is low.

3.2 Analysis of the Proportion of CO2 Emissions in Different Stages of Organic Tea

According to Figure 4, it can be clearly seen that the manufacturing stage accounts for the largest area, accounting for 45.57%, which is due to the complex process in the process links such as enzyme fixation, drying and screening, and the large energy input and consumption, resulting in the large carbon emission; CO2 in the use stage accounts for the second largest, accounting for 30.07%, because the use stage, that is, the soaking and drinking stage of consumers after sale, requires more electricity and water, so the carbon emission is large; The proportion of carbon emissions in the raw material stage is 21.48%. At this stage, water irrigation is used to cultivate tea, and organic ecological fertilizer is used, which has less pollution and carbon emissions are in the middle stage; The proportion of transportation and waste stage is 2.47% and 0.39%, and the consumption of resources in these two stages is very small, so the carbon emission is the lowest.

4. Discussion

In this study, the carbon footprint of Pu 'er organic green tea was evaluated based on the life cycle analysis method. Through on-the-spot investigation, referring to the domestic tea product classification standards, the activity data were collected according to PAS 2050 guidelines. The whole product life cycle of Pu 'er organic green tea was analyzed from five stages: raw material acquisition, manufacturing, transportation, use and waste disposal. The carbon footprint results of each stage of organic green tea life cycle were obtained through carbon footprint accounting.

Taking the whole life cycle of 1kg Pu 'er organic green tea as a functional unit, the carbon emission of each stage of the life cycle was evaluated. It was found that the total carbon footprint of 1 kg Pu 'er organic green tea was 7.68kg. Compared with the carbon footprint study of Azapagic et al. on tea production and consumption in Kenya, 12kg CO2 eq [9] was produced per kg dry tea, and the organic production of Pu 'er green tea made a great contribution to carbon emission reduction. Among them, the carbon emission is the highest in the manufacturing stage, accounting for 3.5kg, accounting for 45.57%. The main reason is that there are many carbon emission factors in this stage, including the consumption of diesel oil and liquefied gas, which are used in tea drying, stir-frying and other technological processes, and the use of various packaging such as tissue paper, aluminum foil paper, plastic bags and tin boxes makes the carbon emission in the manufacturing stage of tea industry the highest. The carbon emission in the use stage is 2.31kg, accounting for 30.07%. Because the use process, that is, the tea soaking and drinking stage of consumers after sale, requires more electricity and water, the carbon emission is large.

Therefore, it is suggested that more energy-saving and emission-reduction measures should be used in the production and use stage of organic tea to reduce carbon emissions at this stage. Specifically, it can be as follows: reducing the use of diesel oil, replacing liquefied petroleum gas with liquefied natural gas, changing mechanical drying and stir-frying into manual operation as far as possible, minimizing the use of various packaging materials and avoiding over-packaging. This study facilitates people to better understand the production process of Pu 'er organic tea and the environmental impact of carbon emission, and also makes clear the development advantages of organic tea products in the future market, that is, more environmental protection and ecology. It is an essential step to analyze the carbon footprint of Pu 'er organic tea in its life cycle. Summarize the experience of ecological sustainable development management in the production technology of tea products in Simao District of Pu 'er, help the development of ecological tea in Pu 'er, and also provide some reference for the ecological development and construction of tea in China.

Acknowledgments

The research was funded by by the Scientific Research Fund of Yunnan Provincial Department of Education project "Research on Building Green Products of Pu'er Tea under the background of" dual-carbon "" (2022J1009).

References

[1] Xu Hongjie. Study on the Technological Path Selection of Yunnan Pu 'er Tea Industry [D]. Kunming University of Science and Technology, 2021.

[2] Yang Piqiong, Xu Wenhui, Chen Shanyan, Shen Xuemei. Looking at the development of black tea industry from the rise of Yunnan Pu 'er tea [J]. Yunnan Agricultural Science and Technology, 2022(05):4-7.

[3] The domestic market potential of organic tea is huge [J]. China Agricultural Information, 2010(03):43.

[4] Rothenberg Dylan O'Neill,Abbas Farhat,Mei Xin,Yan Changyu,Zeng Zhen,Mo Xiaoli,Chen Shiheng,Zhang Lingyun,Huang Yahui.Metabarcoding of organic tea(Camellia sinensis L.) chronosequence plots elucidates soil acidification-induced shifts in microbial community structure and putative function[J].Applied Soil Ecology,2022,178.

[5] Peik Lin Teoh.Comparative Study on In Vitro Anti-Proliferative and Apoptotic Effects of Organic and Non-Organic Tea Extracts[J].Journal of Food Biochemistry,2015,39(6).

[6] Tian Huawei,Siddik Abu Bakkar,Masukujjaman Mohammad.Factors Affecting the Repurchase Intention of Organic Tea among Millennial Consumers:An Empirical Study[J].Behavioral Sciences,2022,12(2).

[7] Hang Thi Minh Bui,Huyen Thi Thanh Nguyen.Factors influencing farmers' decision to convert to organic tea cultivation in the mountainous areas of northern Vietnam[J].Organic Agriculture,2020(prepublish).

[8] Mahmoudi Hashem,Farajpour Mostafa,Afrasiabi Samira.The Preferences of Consumers for Organic Tea:Evidence from a Stated Choice Experiment[J].Journal of the Saudi Society of Agricultural Sciences, 2021(prepublish).

[9] Azapagic A,Bore J,Cheserek B,et al.The global warming potential of production and consump-tion of Kenyan tea[J].Journal of Cleaner Production, 2016,112:4031-4040.

[10] Farshad S F,Hamed K.P,Nejad R M G,et al.Cradle to grave environmental-economic analysis of tea life cycle in Iran[J].Journal of Cleaner Production,2018,196:953-960.

[11] Zhu Yuangui, Wang Fuzhong. Study on the Production Technology of Organic Tea [J]. Modern Economic Information, 2010,No.294(08):169.

[12] Zhao Yugui, Hu Xiangqin, Wu Dazheng. Planting method of Baiyun Chunhao organic tea [P]. Anhui Province: CN 115997607a, April 25, 2023.

[13] Dong Zuxiang, Dong Jiwen, Yang Yingbiao, Dong Tianwu, Chen Guoyun. An organic tea pest monitoring device and control monitoring system [P]. Yunnan Province: CN218830124U,2023-04-07.

[14] Gan Weihua, Chen Jianye. A pest control method for planting organic tea [P]. Guangdong: CN115843608A, 2023-03-28, 2023.

[15] Hou Jianrong. A pest trapping and killing device for planting organic Pu 'er tea [P]. Yunnan Province: CN217850960U,2022-11-22.

[16] He Yunchun. An insect-stained board for planting organic tea [P]. Yunnan Province: CN217850965U, 2022-11-22.

[17] Yu Hao. Research on Green Development Problems and Countermeasures of Tea Industry Based on Net Carbon Footprint [D]. Guizhou University of Finance and Economics, 2022.

[18] Qiang Xu,Kelin Hu, Xiaolong Wang,et al.Carbon footprint and primary energy demand of organic tea in China using a life cycle assessment approach[J].Journal of Cleaner Production,2019.233:782-792.

[19] Zhen H,Qiao Y,Ju X,Hashemi F,Knudsen MT.Organic conversion tea farms can have comparable economic benefits and less environmental impacts than conventional ones-A case study in China.Sci Total Environ.2023 Jun 15;877:162698.

[20] HE Ming-Bao,SX Zong,LI Ying-Chun, et al..Carbon footprint and carbon neutrality pathway of green tea in China[J].Advances in Climate Change Research.

[21] Zhu Qiang, Duan Jihong, Qian Yuhao, Lou Yiling. Carbon footprint analysis of organic rice based on life cycle theory-taking alpine organic rice in Jinzhai County as an example [J]. Resources and Environment in Arid Areas, 2019,33(10):41-46.

[22] He Jihang, Dai Jianjing, Wu Qiuping, et al. Research progress on life cycle assessment of environmental impact of tea industry chain [J]. China Tea, 2023,45(2):7.