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USING CARBON FOOTPRINT TO EVALUATE ENVIRONMENTAL ISSUES OF FOOD TRANSPORTATION

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ABSTRACT. Background: The international trade of food commodities is still growing and food products are transported sometimes for a long distance using various modes. Food transportation issues should be discussed not only in respect to quality and safety concerns but also from environmental point of view. Numerous approaches are proposed to study impacts of food transportation along typical food chain on environment. Carbon footprint based on seems to be an interesting indicator for such analysis.

Material and methods: The analysis carried out in this study is based mainly on data presented in paper and reports published in recent decade, including some opinions available on various internet websites.

Results and conclusions: The greenhouse gas emissions associated food transport along whole food supply chain. Carbon footprint can be used to study various environmental impacts on each chain stage including primary production, food processing, fuel and energy consumption in food distribution, retail issues and product use by consumer during household consumption. Adding these together all of the greenhouse gas emissions gives the total carbon footprint for a product useful to affect consumer nutritional behaviors..

Key words: food transportation, carbon footprint, environmental impact.

INTRODUCTION

Nowadays all enterprises involved in the agrifood sector, from producers, manufacturers, retailers to consumers, are required to be responsible for meeting the fundamental safety requirements for food and feed. However, according to the 'farm to fork' approach , typical food chain contains not only links connected with food processing and storing but also the transport and holding of food commodities ones. Food safety hazards characterized by different frequency and severity risk are identified across all modes of transport. Raw seafood, raw meat and poultry, and refrigerated raw and ready-to-eat foods have the highest overall risks (in descending order) in this context [Ackerley et al. 2010].

Each year, 200 billion metric tons of food are transported globally - 35 percent by land, 60 percent by sea, and 5 percent by air [Bendickson 2007]. Food transportation has a significant impact on environment because of its propensity to increase the volume of greenhouse gas emissions. In the EU countries almost 54 percent of total nitrous oxide, 45 percent carbon dioxide, 23 percent none-methane volatile organic compounds (NMVOC) and 20 percent other gases contributing to global warming are coming from this source. It results not only in the essential degradation of natural environment, but also has a strong negative effect on human health [Badyda 2010] .

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Due to opinion of experts from Eco Evaluator Inc., USA, "when it comes to food imports, air transports burn an excessive amount of fuel. A single loaded airplane can burn thousands of pounds of fuel during takeoff alone. Huge sea vessels and airplanes that are used to transport imported food use fossil fuels and produce more emissions than any other mode of transportation. Naturally, these ships and planes carrying imported goods, upon docking or landing at its destined port, will also need large trucks for the products to be delivered to its final destination. Obviously, if the food source is located a great distance away from its destination, the fossil fuel consumption of the transporting vessel will also be great" [Anonymous 2012].

To reduce the greenhouse gas impact of agri-food sector it's necessary to understand how the production, distribution, retailing and use of agri food commodities results in these emissions which contribute to global warming. One way to understand, and measure, the environmental impact of food transportation issues is to use carbon footprinting method.

The main purpose of this article is to present selected data and examples focusing on this approach to food transportation issues.

WHAT IS A "CARBON FOOTPRINT" ?

Most agro-food manufacturers and suppliers including main international players on worlds markets, are using eco-audit and eco-design principles, including Life Cycle Assessment approach, searching most environmental friendly technological and raw material solutions [Raport DIAS 2003]. Since in recent decades the environmental effects of transportation has become a topic of increasing importance around the world, also more complex LCA transportation studies have been conducted to increase understanding of pollutant emissions along with their consequences, and to develop tools for impact reduction [Fet 2001]. Some researchers have also made efforts to define the long-term direction for future transportation and environmental research from a broader perspective. These analyses provide a general framework for the concept of sustainability, defining the purpose of studying transportation and the environment, which encompasses logistics systems and their impacts. The most widely accepted definition for sustainable development was given by the World Commission on Environment and Development in 1987, and subsequently endorsed by the United Nations at the Earth Summit in 1992:"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." As a result industry has begun to respond and make adaptations to the growing need for sustainable activities [Sathaye et al. 2006]. Therefore, developing and implementing practical and cost-effective carbon mitigation strategies for the complex logistics sector presents a great challenge of crucial importance [McKinnon, 2010, Uvarov, 2011].

Several methods and tools are used to study global impact of human activity on environment. The concept name of the carbon footprint originates from ecological footprint, which was developed by Wackernagel already in the 1990s [Wackernagel 1996] which estimates the number of "earths" that would theoretically be required if everyone on the planet consumed resources at the same level as the person calculating their ecological footprint. A carbon footprint has historically been defined as "the total set of greenhouse gas (GHG) emissions caused by an organization, event, product or person." However, a more practicable definition has been suggested, and namely : "A measure of the total amount of carbon dioxide (CO_2) and methane (CH_4) emissions of a defined population, system or activity, considering all relevant sources, sinks and storage within the spatial and temporal boundary of the population, system or activity of interest." [Wirth et al. 2011] .

To express a carbon footprint as a single number (a common currency), the emissions of greenhouse gases are converted into an equivalent amount of carbon dioxide (CO_2 equivalent or CO_2e). This conversion is based on the relative global warming impact of each gas, and the final carbon footprint is expressed as the weight of carbon dioxide. Since the Kyoto Protocol is an international treaty for controlling the release of GHG from human activities, often this GHGs are referred as "Kyoto gases" (Table 1) [IPPC 2007] .

Table 1. "Kyoto gases" and their Global Warming Potential expressed as CO_2 equivalent
Tabela 1. Potencjał tworzenia efektu cieplarnianego dla tzw. gazów z Kyoto wyrażony jako ekwiwalent CO_2

Greenhouse Gas	**Global Warming Potential (GWP)**
Carbon dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous oxide (N_2O)	298
Hydrofluorocarbons (HFCs)	124 – 14800
Perfluorocarbons (PFCs)	7390 – 12200
Sulfur hexafluoride (SF_6)	22800
Nitrogen trifluoride (NF_3)[3]	17200

Despite the reduction of LCA into a single indictor of climate change, carbon footprinting demonstrates greater appeal than LCA as it is being promoted and diffused outside the scientific community (Finkbeiner 2009).

SIGNIFICANCE OF TRANSPORTATION IN THE FOOD SUPPLY CHAIN EVALUATED BY CARBON FOOTPRINTING METHOD

There is a general agreement that the transport of food accounts for an essential portion of the environmental burden imposed by any stage of typical food chain. Transport - either during the retailing and distributing phase or in the process of household consumption has significant direct impacts on environment. Transportation processes have been shown in many LCA studies to have the largest impact in terms of energy consumption, global warming, acidification and eutrophication [Massari 2003]. The emissions associated with transportation vary by origin and type of food. Weber and Matthews, 2008 estimate that food transportation may account for 50% of total carbon emissions for many fruits and vegetables, but less than 10% for red meat products. Each year, the food system utilizes about 19 percent of the total fossil energy burned in the United States of this 19 percent, about 7 percent is expended for agricultural production, 7 percent for processing and packaging, and 5 percent for distribution and food preparation by consumers [Pimentel et al. 2006].

For example, in case of the dairy sector, it has been estimated that the distribution of dairy products to retailers requires much more energy than does the transport of the milk from farm to dairy. In the farming phase transport play a role due to the movement of animal feed and livestock, although a larger component in the overall impact of this life cycle stage seems to be the use of nitrogen based fertilizers and pesticides in the production of the cereals which generally constitute animal feed. Cows burping methane are also indicated as source of environmental problems, so, due to general assessment of problem, about 73 percent of the carbon footprint comes from dairy farming (Fig. 1) [Anonymous 2012b].

The reduction of fuel consumption of transport modes used along all food chain stages is one of critical factor influencing product carbon footprint. In respect to fuel type specific carbon dioxide emissions vary from 2.3 kg to 3,3 kg CO_2 per 1 kg of coal and gasoline, respectively [Engineering TollBox, 2012]. Fossil fuels are virtually nonrenewable natural resources. Differences in fossil fuel requirements for vegetable protein and meat protein production strongly depend on the intensity of agriculture. Depending on the relative intensities of agricultural practices and attributing all energy inputs to the production of foodstuffs, the efficiency of fossil fuel use may be a factor 2.5-50 better for vegetable proteins, if compared with animal husbandry. In European countries, this difference will usually be a factor 6-20 to the advantage of soybean-based protein food [Reijnders and Soret 2003] .

Within the developed world there are four basic transport modes for shipping large quantities of packaged products: water, rail, truck, and air. Although certain food supply chain systems require bulk transport, such as rail, barge or in water, truck transportation dominates most logistic systems, especially toward the consumer end of the chains. Particularly for perishable foods, trucking remains cheapest and flexible mode of food transport [Ackerly et al. 2010]. To compare transport modes with regard to energy usage and resultant emissions, a ton-km as the movement of 1 metric ton of cargo over 1 km was proposed by Wakeland et al. 2012. Table 2 shows that these modes have very different energy and emissions profiles.

Life cycle stage	Raw material production	Manufacture/ processing	Logistics/ distribution	Retail	Use by consumer	Recycling and disposal
Carbon footprint	73%	9%	3%	10%	3%	2%

Fig. 1. The relative percentage of carbon footprint in raw milk production
Rys. 1. Względny udział procentowy etapów produkcji mleka surowego w tworzeniu śladu węglowego

Table 2. Energy and emissions per ton-km in dependence of transport mode
Tabela 2. Energia i emisje w przeliczeniu na tonokilometry w zależności od środka transportu

	MegaJoules per ton-km	Kg CO_2eq per ton-km
International water-container	0,2	0,14
Inland water	0,3	0,21
Rail[a]	0,3	0,18[a]
Truck[b]	2,7	1,8
Air[c]	10	6,8

Note that utilization and backhaul rates will affect all figures
[a] May depend on whether diesel or electric power is used
[b] Depends on size and type of truck, power source
[c] Includes effects from radiative forcing

Follow data reported by Ackerly et al. 2010 again in the United States, about 80 percent of all food shipments and 91 percent of all temperature-controlled freight shipments, including about 28.5 million tons of refrigerated fruit and vegetables are transported by truck. Short sea shipping, using ocean-going vessels for delivering cargo domestically, is popular in Europe and also holds promise for replacing many truck deliveries in the United States.

When it comes again to typical "farm-to-fork" food chain, environmental impacts of transportation in respect to processing phase should be taken into consideration, too. From discussion paper of Massari, 2003 it emerged that European and Japanese companies had much higher levels of production efficiency than their US counterparts. A reason for this could be that Europe and Japan both have more developed environmental management systems and , in consequence, reduce energy costs, waste disposal and treatment charges. Within the plant, key contributors to energy/carbon use include processing equipment, such as ovens, dehydrators, retorts and pasteurizers; coolers and freezers; compressed air systems; air-handling systems for clean rooms; and lighting. The processor may need to replace certain pieces of equipment to improve energy efficiency. An example would be switching some transportation volume to less CO_2-intensive modes or replacing motors with new ones that are more energy efficient and sized properly to the equipment they power. Internal transport optimization and better control systems can help reduce energy demand and thus the carbon footprint [Connolly 2012].

Transportation is an important factor, both during the retail and food distribution phases and in the process of household consumption. It has been calculated [Massari 2003] that the energy spent by household transport f. e. in the Netherlands, for shopping and eating out (assuming an average 3.5 km journey by car, once a week, for food shopping) amounts to

1280 MJ annually. The energy spent in car use for eating out has been estimated at 20 MJ per outside meal. According to DEFRA report [Forester et al. 2006], the environmental impact of car based shopping are greater than those of transport within the distribution system itself. The environmental impact of aviation is important for air-freighted products, but such product are a small proportion of food consumed. Transportation is, however, only one of the components in the overall consumption phase, which also includes conservation, preparation and final use, each one having its own direct environmental impact [Massari 2003].

To measure the full impact of a product, we measure greenhouse gas emissions across its full life-cycle, from "farm-to-fork". This includes emissions from the extraction of raw materials, direct gas emissions during the agricultural and processing stages, waste outputs, use of packaging materials, fuel consumption in distribution, energy consumption in processing, retail and product use by customers, and disposal at end-of-life. Adding these together all of the greenhouse gas emissions gives the total carbon footprint for a product. These data are used sometimes to compare plant and animal origin products in respect to its share in the total CO_2 emission. The amount of greenhouse gases caused by the production of food differs very much from one food type to the other (Table 3) [Anonymous 2011].

Table 3. Comparison of CO_2-Emissions for various food products (in g CO_2e per kg food)
Tabela 3. Porównanie emisji CO_2 dla różnych produktów spożywczych (w g ekwiwalentu CO_2 na kg produktu)

Food Group	Food	CO_2 eq -Emissions (in g per kg foods)
Meat and sausages	Beef	13300
	Raw sausages	8000
	Ham (pork)	4800
	Poultry	3500
	Pork	3250
Milk-and dairy products	Butter	23800
	Hard cheese	8500
	Cream	7600
	Eggs	1950
	Quark (curd)	1950
	Farmer cheese	1950
	Margarine	1350
	Yogurt	1250
	Milk	950
Fruits	Apples	550
	Strawberries	300
Baked goods	Brown bread	750
	White bread	650

Based on the above data some "green oriented" organizations postulate to eat only environmental friendly and "climate change friendly" food products. The growing number of publications explores the environmental burden or carbon footprint of diet and the implications of dietary recommendations for the environment [Eshel and Martin 2006, Marlow et al. 2009,]. Leading food retailers on the market footprinted own brand food products across the store to provide advice to suppliers on how they can become more resource efficient, and to advise customers on how they can reduce their household carbon footprint and save money on energy use at home. For example, in a typical 420g can of Tesco's baked beans, the energy used to cook the beans during manufacture contributes 30g CO_2e, and a further 120g CO_2e comes from the energy and raw materials used to make the tin can [Anonymous 2012b]. Methodological issues aside, Figure 2 illustrates and summarizes well this approach as a draft categorization of food products according to their carbon footprint. On top of the pyramid, beef and dairy products are some examples of carbon intensive food products, pork and fish are less intensive, while vegetables belong to the lowest category in terms of GHG emissions [Bakas 2010]. Motivations of purchasing local, organic foods, calculating food miles for individual foodstuffs and choosing food categories with reduced carbon footprint should be issues for discussion in separate elaboration.

Fig. 2. Food products groups in Carbon Footprint (CF) pyramid
Rys. 2. Grupy produktów spożywczych w piramidzie śladu węglowego

CONCLUSIONS

In summary, it is demonstrated in this work that the greenhouse gas emissions associated food transport along whole food supply chain. Carbon Footprint is an issue which is continuing to grow in importance and can be used to study various environmental impacts on each chain stage including primary production, food processing, fuel and energy consumption in food distribution, retail issues and product use by consumer during household consumption. Carbon footprinting method enables to calculate global impact of foodstuffs and, in consequence, can affect significantly on food choice and purchasing decisions of consumer.

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ZASTOSOWANIA ŚLADU WĘGLOWEGO DO OCENY ASPEKTÓW ŚRODOWISKOWYCH ZWIĄZANYCH Z TRANSPORTEM ŻYWNOŚCI

STRESZCZENIE. **Wstęp:** Stale rośnie znaczenie międzynarodowego handlu żywnością, a produkty spożywcze przebywają niekiedy bardzo znaczne odległości przy użyciu różnego typu środków transportu. Zagadnienia związane z transportem żywności powinno rozpatrywać się nie tylko w aspekcie jakości i bezpieczeństwa żywności lecz także w aspekcie środowiskowym. Proponuje się liczne metody dla oceny oddziaływania transportu żywności na środowisko w całym typowym łańcuchu żywnościowym. Ślad węglowy wydaje się interesującym wskaźnikiem przydatnym do takiej analizy.
Metody: Analiza wykonana w niniejszym pracowaniu została głownie przeprowadzona w oparciu o publikacje opublikowane w ostatnim dziesięcioleciu z uwzględnieniem niektórych opinii dostępnych na różnych stronach internetowych.
Wyniki i wnioski: Emisje gazów cieplarnianych towarzyszą transportowi żywności w całym łańcuchu żywnościowym. Wskaźnik śladu węglowego można stosować do oceny różnych oddziaływań środowiskowych na każdym etapie łańcucha dostaw, włączając produkcję pierwotną, przetwarzanie żywności, zużycie energii i paliwa podczas dystrybucji żywności, handlu, a także w działaniach konsumenta w gospodarstwie domowym. Sumowanie emisji gazów cieplarnianych na wszystkich wymienionych etapach prowadzi to oszacowania śladu węglowego produktu przydatnego jako narzędzie oddziaływania na zachowania żywieniowe konsumentów.

Słowa kluczowe: transportowanie żywności, ślad węglowy, oddziaływanie na środowisko.

ANWENDUNG VON CARBON FOOTPRINT ZUR BEURTEILUNG VON UMWELTBEEINFLUSSUNGEN IM LEBENSMITTEL-TRANSPORT

ZUSAMMENFASSUNG. Einleitung: Die Bedeutung des internationalen Lebensmittehandel wird immer größer und die Lebensmittelprodukte transportiert man manchmal sehr weit unter Anwendung von verschiedenen Transportmitteln. Die Fragen, die mit dem Lebensmitteltransport verbunden sind, sollen daher nicht nur in Hinsicht auf die Qualität und Sicherheit diskutiert, sondern auch unter Berücksichtigung von Umweltbeeinflussungen erörtert werden. Man schlägt zahlreiche Maßnahmen für Beurteilung der Einflussnahme des Lebensmitteltransports auf die Umwelt entlang des ganzen typischen Food chain vor. Carbon footprint scheint ein interessanter brauchbarer Indikator für eine solche Analyse zu sein.
Methoden: Die im Rahmen dieser Publikation durchgeführte Analyse wurde anhand der im letzten Jahrzehnt veröffentlichten Publikationen und Berichte unter Berücksichtigung einiger Meinungen aus verschiedenen Internetseiten ausgearbeitet.
Ergebnisse und Schlussfolgerungen: Die Emission von atmosphärischen Gasen begleitet den Lebensmitteltransport im Bereich des ganzen Food chain. Man kann Carbon footprint als den Indikator für die Beurteilung von unterschiedlichen Umweltbeeinflussungen auf jeder Etappe des Food chain benutzen, einschließlich der primären Produktion, der Lebensmittelverarbeitung, des Energie- und Kraftstoffverbrauches bei Lebensmittelverteilung oder im Handel, ferner der Aktivitäten der Verbraucher im Haushalt. Die Summierung von Emissionen der atmosphärischen Gase auf den erwähnten Etappen führt zur Einschätzung des Carbon footprint für die jeweiligen Produkte, welchen man als brauchbares Tool für die Beeinflussung von Ernährungsverhalten der Konsumenten einsetzen kann.

Codewörter: Lebensmitteltransport, Carbon footprint, Umweltbeeinflussung.

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