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Life-cycle impact assessment of organic and non-organic grass-fed beef production in Japan

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ABSTRACT

Beef production, especially when based on the calves from suckler cows, typically has the greatest environmental impacts among various livestock production systems. Conventional beef production in Japan uses a large amount of imported concentrate feed, which results in substantial environmental impacts. Yakumo Farm, located in northern Japan, produces grass-fed beef using only farm-grown feed. Pesticides and chemical fertilizer were used in the past, but organic management was introduced at the farm more recently. We assessed the environmental impacts of grass-fed beef production at Yakumo Farm before and after the introduction of organic management (hereafter, non-organic and organic, respectively), and a conventional Japanese (hereafter, conventional) system using life-cycle assessment (LCA). We constructed the LCA models based on data collected at Yakumo Farm, from the literature and from LCA databases. The LCA system boundaries included feed production, transportation, processing, animal management, enteric fermentation, and manure and its management. The functional unit was defined as 1 kg of cold carcass weight of beef steers. The impact of each system was determined regarding its potential contribution to global warming, acidification, and eutrophication, as well as its energy consumption. Both the organic and non-organic systems had much smaller impacts on acidification, eutrophication, and energy consumption than the conventional system. The impact on global warming associated with the organic system was equivalent to the conventional system, whereas for the non-organic system it was greater than for the conventional system. Generally, the exclusion of the process of feed transportation reduced the environmental impacts. The use of chemical fertilizer increased the global warming-related impact in the non-organic system. Therefore, we concluded that introducing organic management to Yakumo Farm mitigated its environmental impacts. Our results provide implications for mitigating the environmental impacts caused by beef or other livestock production not only in Japan, but also in other countries depending upon imported feed.

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1. Introduction

Sustainability of food production has attracted much attention in recent decades. In general, livestock products bear greater environmental burdens than food of plant origin (excluding greenhouse crop production, for example) (Mogensen et al., 2009; Schmidinger and Stehfest, 2012). de Vries and de Boer (2010) compared the environmental impacts of several livestock products, and reported that beef production used the most land and energy, and had the greatest global warming potential (GWP). It

was also found that beef production systems based on the calves from suckler cows had greater environmental impacts than those based on dairy calves (de Vries et al., 2015). Nguyen et al. (2010) evaluated the environmental impacts of the EU suckler-based beef production system and compared them with those of the conventional Japanese system (Ogino et al., 2004, 2007). They reported that these systems had similar levels of GWP, but that the Japanese system had greater acidification and eutrophication potentials, and used much more energy. Peters et al. (2010) compared the GWP and energy use among beef production systems in Australia and other countries including Japan. According to their comparisons, Japanese beef production had the greatest GWP and used, by far, the most energy. Other research also indicated the

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considerable GWP (Stackhouse-Lawson et al., 2012) and energy consumption (Ogino et al., 2016) of Japanese beef production. Thus, beef produced in Japan can be regarded as a food with a great environmental load.

Suckler-based beef production in Japan is divided into the cow-calf and fattening (backgrounding and finishing) stages. In the conventional beef production system in Japan, the fattening stage has greater GWP than the cow-calf stage (Ogino et al., 2004, 2007), which contrasts with systems in the USA (Lupo et al., 2013; Pelletier et al., 2010; Stackhouse-Lawson et al., 2012), Canada (Beauchemin et al., 2011), and Uruguay (Picasso et al., 2014). Japanese beef production typically uses a non-grazing housing system that relies largely on concentrate feed especially during the fattening stage. Most concentrate feed used in Japanese livestock production (88% in 2013, based on total digestible nutrient) is imported from other countries, mainly the USA, although most roughage (77%) is produced within Japan. Hence, the environmental impacts of Japanese beef production are enhanced not only by production of a large amount of concentrate feed but also by feed transportation.

Life-cycle assessment (LCA) is a widely accepted method for evaluating and comparing the environmental impacts of livestock production systems (de Vries and de Boer, 2010). Numerous comparative LCAs among different beef production systems have been conducted to assess the mitigation of environmental impacts (reviewed by de Vries et al., 2015). de Vries et al. (2015) compared the environmental impacts of beef produced in contrasting systems in terms of the type of diet fed to fattening calves (roughage- or concentrate-based) and the type of production (organic or non-organic). They reported smaller GWP and energy consumption for concentrate-based systems compared with roughage-based systems, whereas no clear patterns were found in their acidification and eutrophication potentials. In addition to this, GWP and energy consumption were smaller in organic systems than in non-organic systems, but organic systems had greater acidification and eutrophication potentials.

Yakumo Experimental Farm, Field Science Center, Kitasato University School of Veterinary Medicine (Yakumo Farm, hereafter) is located in southwest Hokkaido in northern Japan (42°15'N, 140°8'E). Yakumo Farm produces grass-fed beef using only farm-grown feed, which is distributed as “Kitasato Yakumo Beef” (hereafter, Yakumo Beef). Yakumo Farm had used pesticides and chemical fertilizer until 2002 and 2004, respectively. Since 2005, the farm has been managed organically. Subsequently, Yakumo Beef was certified as Japan's first organic beef. Yakumo Beef has few environmental impacts from feed transportation (only within the farm), in contrast to beef produced using the conventional Japanese system, which is based on concentrate feed that is transported long distances, such as from the USA to Japan. Large amounts of carbon dioxide, sulfur oxides and nitrogen oxides are emitted and energy is used to a large degree in the process of feed transportation (Table S1). Therefore, it is hypothesized that Yakumo Beef has smaller GWP, acidification and eutrophication potentials, as well as less energy consumption than conventionally produced beef, in contrast to the conclusions derived by de Vries et al. (2015). However, like other grass-fed beef production systems (Capper, 2012; Lupo et al., 2013; Pelletier et al., 2010), production efficiency (body weight gain) at Yakumo Farm is lower than that of the conventional system (Table 1), which might enhance the environmental impacts per product weight, as reported in previous studies (Beauchemin et al., 2011; Lupo et al., 2013; Pelletier et al., 2010).

In this study, we used LCA to evaluate the environmental impacts of grass-fed beef produced at Yakumo Farm before and after the introduction of organic management (hereafter, non-organic and organic, respectively), and compared the results with those for the conventional Japanese (hereafter, conventional) system.

Table 1

Description of the three beef production systems.

	Yakumo Farm		Conventional
	Organic	Non-organic	
All cattle			
Grazing period per year (days)	168	168	0
Cow-calf			
Age at first calving (days)	779	779	757
Calving interval (days)	395	395	417
Calving occurrences per cow	7	9	9
Lactation period (months)	6	6	3
Steer			
Daily weight gain (kg)	0.63	0.65	0.95
Age at slaughter (days)	1089	885	761
Live weight at slaughter (kg)	724	615	722
Cold carcass weight (kg)	410	339	465

2. Materials and methods

2.1. Goal and scope definition

The targets of this analysis were steers. The varieties of cattle were Japanese Shorthorn and its crossbreeds at Yakumo Farm, and Japanese Brown in the conventional system whose market weight has been similar to that of Yakumo Beef in recent years. Note that the targeted varieties of cattle are different from the Japanese Black variety. The environmental impacts of Japanese Black beef production have already been assessed in several studies (Ogino et al., 2004, 2007; Oishi et al., 2013; Tsutsumi et al., 2014). Although the environmental impacts of conventional production of Japanese Brown beef were assessed by Tsutsumi et al. (2017), the methods of calculation are slightly different from those employed in this study. In the current study, the functional unit was defined as 1 kg of cold carcass steer weight.

The data for the production systems (including the cattle growth curve, grazing schedule, resources used for pasturing, forage nutrient values and reproductive performance) of Yakumo Farm were obtained for 1997–2004 for the non-organic system and 2006–2013 for the organic system. The data for the conventional system were obtained from Nihon Akaushi Touroku Kyoukai (2000), NARO (2009, 2010) and the Agriculture and Livestock Industries Corporation (2016). The system boundaries included feed production, feed processing, feed transportation, animal management, enteric fermentation, and excreta and its management. All resources used in the system were considered, such as the energy used to produce the chemical fertilizer; however, capital goods, such as barns and machinery, were not considered.

2.2. Production systems of Yakumo Farm

In the organic and non-organic systems at Yakumo Farm, the following issues were common. All cattle were grazed on pastures from mid-May to mid-October without supplemental feed, and managed in barns during the remaining period (Tables 1 and 2). In the barns, the cattle were fed farm-grown roughage. The lactating period was six months.

There were no differences in age at first calving and calving interval between the organic and non-organic systems, whereas calving occurrences per cow in the non-organic system were higher than those in the organic system. Both grass silage and hay were used as roughage in the non-organic system, but only grass silage was used in the organic system. The fattening period was longer and both live weight at slaughter and carcass weight were heavier in the organic system than the non-organic system. The fattening period has been gradually extended since 2003 based on a

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