MEAT SUPPLY CHAIN IN THE PERSPECTIVE OF UN SDGS

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Keywords: meat and meat products, supply chain, United Nations, sustainability development goals

Abstract
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Results and discussion

**SDG6 — Clean water and sanitation and the meat supply chain**

The need for clean, accessible water is one of the UN SDGs since the world is striving for sufficient fresh water opposed to water scarcity, poor water quality and inadequate sanitation that has a negative severe impact on food security throughout any food supply chain [12]. The meat industry requires adequate supply of potable water for both meat processing and hygiene and sanitation to ensure meat and meat products are not contaminated. Therefore, one of key targets associated with meat and meat products is how to produce more using less water [4].

Meat slaughtering and meat processing are the two links in the meat supply chain that require potable water while they also discharge significant volumes of pollutant wastewater [13]. However, the entire chain is a big user as water is important for live animals at farms and when entering the slaughterhouse as well as for hygiene and sanitation of slaughterhouses, meat processing plants and retail, and finally for use at households for meat preparation [8, 14].

Water used in the meat supply chain comes from different sources, such as ground or surface water and is extensively used for numerous technological purposes in different quantities satisfying requirements outlined in water safety and quality standards [15]. Also, in some meat processing products it is a primary ingredient like in the case of hams and sausages. In these cases, water needs to be of highest “potable” quality. When used for non-processing purposes such as boiler feed water, fire-extinguishing water, pasteurizing, heating or cooling medium, quality of such water is medium to high [16]. As wastewater from meat industry may be a big environmental polluter, it is important to protect all water sources and treat wastewater with similar care [15].

**SDG7 — Affordable and clean energy and the meat supply chain**

Different types of energy are used throughout the meat supply chain basically for machines and equipment, for controlling temperature regimes (heating / refrigerating) and for transportation purposes [14, 17]. Its source is deployed in terms of clarifying consumption from electric energy, thermal energy and other sources of energy, such as types and quantities of fossil fuels.

Advanced housekeeping practices in the meat sector can obtain improvements while additional savings can be made through promoting energy efficiency associated with equipment and heat recovery systems [18, 19]. A promising approach in reducing energy consumption and related energy costs is through energy management [20]. Some types of organic solid waste classified as biomass can facilitate energy recovery instead of their disposal [21]. Biomass to energy conversion are routes to energetic and economic benefits [21, 22]. Recovering methane from manure is another potential of energy improvements in the meat sector [19]. This type of waste can also be used as a secondary fuel for thermal energy [23]. The main goal of thermal disposal of (organic) wastes is its conversion to safe materials, as well as in reducing its weight and volume [24].

**SDG12 — Sustainable consumption and production and the meat supply chain**

From 1961 to 2011, global meat consumption almost doubled from 23.1 kg per capita per annum to 42.2 kg per capita per annum [25]. Regarding expected population growth, total consumption will increase yearly by almost 1.5% [26]. Major contributor to global meat production originates in the pig sector while the poultry sector is the fastest growing livestock sector as it’s a source of healthy high protein and low-fat type of meat [27–29]. Consumption of animal-based proteins has increased during a half-century period worldwide (1961–2011), from 61 g per capita per day up to 80 g per capita per day [25].

However, not only from a nutritional point of view, consumption of meat is also studied in terms of its environmental impact [30]. The FAO has coined a new term “sustainable diet” associated to diets with optimal healthy and low environmental impacts [31]. As a result, some authors claim that main trigger in “sustainable diets” is to avoid meat and meat products due to their severe environmental impacts. However, global warming potential of meat consumption compared to other products is not so much higher as one would assume analyzing some media and literature. Also, most authors associate climatic impact of food with both production and consumption [30], with limited number of papers that analyzed impact of meat consumption [32]. Finally, in line with various dietary habits that exclude consumption of meat and meat products such as veganism, vegetarianism, raw foodism, or fruitarianism, still a large majority of people eat meat regularly or occasionally [33]. Such environmental pressure on changing dietary habits is still more a scientific que than an everyday routine. One of a few studies that analyzed replacement of animal origin food with plant-based substitutes revealed some potentials in changing dietary habits in parallel with decreasing environmental impacts [34].

**SDG13 — Climate action and the meat supply chain**

Speaking about climate action (SDG13), agriculture is one of sector that will play a big role in responding to climate change [4]. Based on the Paris Agreement [35], two main actions arise: (i) limiting the global warming to below 2°C above pre-industrial levels and to pursue efforts in limiting the increase of temperature to 1.5°C [36] and (ii) preventing these threats to food systems [37]. Main challenge is how to produce sufficient amounts of food for the world’s population from the perspective of observing interaction between climate change and food production. The impact of meat production is twofold in terms that meat production has an impact on climate change and *vice versa*, climate change has an impact on meat production [38].
Analysis of meat on climate change can be observed from life-cycle assessment studies, such as analysis of pork, beef and chicken meat production [33]. These studies confirm that carbon footprint (expressed as carbon-dioxide equivalent — CO2e) is the main predictor of evaluating climate change impact of the meat supply chains [39]. For calculating CO2e, it is necessary to measure all greenhouse gasses emissions [40]. In parallel, ozone depletion potential expressed as CFC-II or R11 equivalents is an additional indicator used to measure the potential for reducing the protective stratospheric ozone layer [41]. This indicator indirectly affects climate change and is associated with maintaining cold chains and using refrigerants for chilling / freezing [42]. These cold chains are vital for keeping meat safe since inadequate temperatures inhibit growth of harmful microorganisms [43].

Households are responsible for preparing meat but also for discarding meat waste [44]. Reasons for discarding meat waste are expired date and rotten taste and/or smell [45]. In order to maintain meat safety, control of the cold chain joint with expiring date care are very important [38] as consumers are the weakest link in cold chains.

Temperature increase joint with climate variability affect quality of feed [46] causing an increase of mycotoxins in crops used for feed [47]. As an example, maize represents a typical crop used in feed production where presence of fumonisins is directly correlated with chronic exposure [48]. Second threat observed at farm levels are animal diseases caused by temperature rise such as death of animal further causing growth of pathogens, parasites and various vector-borne diseases [46].

Heat stress causes additional water needs for animals. Their response are dietary changes (less feed / more water) and changes in reproductive and productive effectiveness [49]. These changes lead to energy disbalances and reduction of animal weight [50] causing decrease of meat production by growth and carcass weight [49], economic losses [51]. Finally, reproduction efficiency during heat stress affects animal fertility [52], embryo development and pregnancy rate [53]. It is assumed that temperature rise may cause up to 30% of biodiversity loss of both plants and animals [54]. Depending on the region, highest risks linked with livestock and breed elimination are with chicken, followed by pigs and cattle [46].

Indicators associated with UN SDGs
To calculate impacts associated with selected UN SDGs, it is common to introduce and calculate environmental performance indicators (EPIs) defined as a “measurable representation of the status of operations, management or conditions related to environmental aspects” [55]. To evaluate meat production, it is important to define a functional unit (FU) in which the impacts are presented and to define formula as this is the basis for all further comparisons [11].

In the meat supply chain, the most common FUs are one kg of livestock [56, 57], one kg of carcass [58, 59] and one kg of meat / meat products [60].

In every meat supply chain, it is common to calculate consumptions and discharges per meat FUs such as water consumption per FU and wastewater discharge per FU directly associated with SDG6 [14, 19, 42] or energy-to-meat ratio, associated with SDG7. As presented above, global warming potential is recognized as an environmental indicator associated with the meat chain [39], linked with SDG13. The GWP is calculated for each link of the meat supply chain.

Table 1 depicts main indicators associated with four SDGs and the meat supply chain [15, 33].

Considering the link of the four UN SDGs and the meat supply chain, Figure 1 depicts the most influential UN SDGs in terms of its severity and time-scale associated with all five links in the meat chain. The most severe and long lasting stage is at farms with SDG13 as the most influential. Slaughtering and meat processing are activities that lasts short (related to one FU) but the overall impact of slaughtering and meat processing on water consumption and wastewater discharge is high (SDG6). Within retails, meat can be stored for a long period of time, but the impact is not so high, mainly associated with energy consumption for maintaining the cold chain (SDG7). Finally, lowest impact is associated with meat consumers / households where meat is often consumed within 7 days from purchasing. This activity is mostly associated with SDG12.

<table>
<thead>
<tr>
<th>Impact associated with UN SDGs</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time-scale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long</td>
<td>Retail</td>
<td>7</td>
</tr>
<tr>
<td>Short</td>
<td>Households</td>
<td>12</td>
</tr>
<tr>
<td>Slaughterhouses</td>
<td>13</td>
<td>6</td>
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<tr>
<td>Meat processing</td>
<td>13</td>
<td>6</td>
</tr>
</tbody>
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Figure 1. Four UN SDGs and their impacts on the five links in the meat supply chain

Other UN SDGs and the meat supply chain
Adapting to climate change for small — scale livestock farms is needed to enhance food security (SDG2 — Zero Hunger) and reduce poverty (SDG1 — No Poverty) of all types of small farmers [61, 62]. This is pronounced since 80 percent of extremely poor people live in rural areas depending on various aspects of agriculture — farming, fisheries and forestry [4]. Improvement of food (meat) trade is in direct correlation with making accessible and affordable safe and healthy meat (SDG2 — Zero Hunger; SDG3 — Good health and well-being). Considering that three billion people receive 20 percent of their daily animal protein intake from fish, it is obvious that sustainable management of oceans, seas and marine resources is important for the fish supply chain, namely sustainable fisheries [4]. Modernization of meat processing can indirectly impact this...
supply chain, with more use of digital technologies, optimization and innovation of processing, including Food Industry 4.0 supported by efficient infrastructures [63]. This may be connected with SDG9 — Industry, motivation and infrastructure.

Finally, all stakeholders connected with the meat supply chain (legal authorities, inspection services, academia) should act as partners in improving this chain aligning to the motivation of achieving SDG 17 — Partnerships for the goals. A good example is the technical committee ISO/TC34 ‘Food products’ [64] declaring that they contribute to the following SDGs (SDG1 — No Poverty, SDG2 — Zero Hunger, SDG3 — Good health and well-being, SDG5 — Gender equality, SDG8 — Decent work and economic growth, SDG10 — Reduced inequalities, SDG11 — Sustainable cities and communities, SDG12 — Responsible consumption and production, SDG13 — Climate action, SDG15 — Life on land and SDG16 — Peace, justice and strong institutions) with published food related standards.

Table 1. Indicators associated with four SDGs and the meat supply chain

<table>
<thead>
<tr>
<th>UN SDG</th>
<th>Indicator</th>
<th>Formula [unit]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Consumption of water per FU</td>
<td>$\frac{\text{Consumption of water [L]}}{FU \ [\text{kg of livestock}]}$</td>
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<tr>
<td></td>
<td></td>
<td>$\frac{\text{Consumption of water [L]}}{FU \ [\text{kg of carcass}]}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\frac{\text{Consumption of water [L]}}{FU \ [\text{kg of meat product}]}$</td>
</tr>
<tr>
<td></td>
<td>Reuse of water [%]</td>
<td>$\frac{\text{Water reuse [L]}}{\text{Water reuse [L]} + \text{Water consumption [L]}} \times 100$</td>
</tr>
<tr>
<td></td>
<td>Water quality index (WQI)</td>
<td>Ranking the WQI from 1–100 (depending on the legislation / methodology applied and parameters measured). The ‘rule of the thumb’ is ‘the higher the WQI, value, the better the quality’ of water.</td>
</tr>
<tr>
<td></td>
<td>Discharge of wastewater per FU</td>
<td>$\frac{\text{Discharge of wastewater [L]}}{FU \ [\text{kg of livestock}]}$</td>
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<tr>
<td></td>
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<td>Water efficiency [%]</td>
<td>$\frac{\text{Water consumption [L]}}{\text{Wastewater discharge [L]}} \times 100$</td>
</tr>
<tr>
<td></td>
<td>Consumption of energy per FU</td>
<td>$\frac{\text{Consumption of energy [MJ]}}{FU \ [\text{kg of livestock}]}$</td>
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<td></td>
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<td></td>
<td>$\frac{\text{Consumption of energy [MJ]}}{FU \ [\text{kg of meat product}]}$</td>
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<tr>
<td></td>
<td>Global warming potential</td>
<td>[ \text{GWP} = \sum_{i} \text{GWP}_i \times m_i \ [\text{kgCO}_2]]</td>
</tr>
</tbody>
</table>

Legend: FU — Functional unit (livestock, carcass, meat / meat product); GWP — Global warming potential.
Conclusion
Considering meat customers (retail / consumers), meat producers (farms / slaughterhouses / processors) and UN SDGs as cornerstones of an interactive triangle, the area within elevates a perspective of improvement opportunities in terms of sustainable production and consumption associated with SDG12. It is expected that this will pave the way in supporting sustainable technologies as well as sustainable diets promoting both sustainable and nutritional values associated with all types of meat and meat products and leaving the (meat) consumers with a free choice. In parallel, striving towards SDG17 — Partnerships for the goals enables deeper fulfillment of all UN SDGs and all stakeholders in the meat supply chain continuum. It is obvious that further attempts are needed to pave the way for fulfilling the UN SDGs' targets and exceeding expectation of all meat supply chain stakeholders.

REFERENCES

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The author bears responsibility for the work and presented data.

The author declares no conflict of interest.