Atmospheric Environment 103 (2015) 43–52

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Linkage of food consumption and export to ammonia emissions in Canada and the overriding implications for mitigation

S.C. Sheppard [a, *], S. Bittman [b]

[a] ECOMatters Inc., Pinawa, Manitoba R0E 1L0, Canada
[b] Agriculture and Agri-Food Canada, PO Box 1000, Agassiz, British Columbia V0M 1A0, Canada

HIGHLIGHTS

- Consumer food choices have substantial but inadvertent impact on ammonia emissions.
- Food and animal export leaves an ammonia emission legacy in Canada.
- Best management practices may be less effective than consumer choice.

ARTICLE INFO

Article history:
Received 8 September 2014
Received in revised form
30 November 2014
Accepted 9 December 2014
Available online 10 December 2014

Keywords:
Consumption
Food
Best management practices
Ammonia emissions
Livestock

ABSTRACT

Ammonia (NH_3) emissions from agriculture to the atmosphere, along with emissions of other pollutants from a variety of sources, are of concern to agriculture worldwide. National emissions from agricultural sources in Canada are linked to domestic consumption and export demand for agricultural products. The onus to limit emissions is often directed to the producers, but the marketplace and consumer are also responsible for the environmental impact of their choices. This objective of this study was to quantitatively link agricultural NH_3 emissions to per person consumption of food and protein and to agricultural exports from Canada. There are substantial differences in the NH_3 emissions per unit consumed protein among the various food types. As a result, shifts in the Canadian diet have had a large impact on relative per person NH_3 emissions. From 1981 to 2006, the total per person protein intake in the Canadian diet increased about 5%, but NH_3 emission related to that diet decreased 20%. This is largely related to consumption of less beef, which has a high emission per unit of meat or protein, and more poultry and cereals which have much lower emissions. Although these changes in diet were not because of environmental concerns by the consumers, they had substantial effects on national-level emissions. These consumer driven effects may well exceed the possible effects of best management practices intended to address NH_3 emissions at the producer level. Note that the Canadian population has increased 50% from 1981 to 2006 and meat and egg exports increased 570%, so that total emissions from food production in Canada have increased. Our results imply there will be further effects on national NH_3 emissions because of dietary and export drivers that are generally outside the scope of agro-environmental policy.

1. Introduction

One of the absolute signatures of animal life is the production of ammonia (NH_3), a necessary by-product of the breakdown of protein. Apart from being a toxic gas in confined spaces, NH_3 can lead to direct toxicity to plants (Sheppard, 2002; Krupa, 2003; Stevens et al., 2011) and can cause formation of aerosols that are transported long distances and are potentially linked to human health issues, to soil acidification, to eutrophication of fresh and coastal waters, and to losses of plant diversity (Ellis et al., 2010). Intensive livestock operations, especially when they are concentrated in a region, are hot spots of NH_3 emissions (e.g., Hristov et al., 2011), and low-cost practical abatement technologies are few and are somewhat limited and often no more than 30% effective on overall farm emissions (e.g., Reidy and Menzi, 2007; Sheppard and Bittman, 2013). Fertilizer and manure application to crops used for food

* Corresponding author.
E-mail addresses: sheppards@ecomatters.com (S.C. Sheppard), Shabtai.Bittman@AGR.GC.CA (S. Bittman).

http://dx.doi.org/10.1016/j.atmosenv.2014.12.023
1352-2310/

and livestock feed are major non-point sources of emissions. Effectively, a significant portion of the NH_3 originating from livestock waste and fertiliser use is a fugitive gas that will escape to the atmosphere under typical farm management systems. Emission of NH_3 is a major pathway for loss of reactive N from farms. Thus it is appropriate to consider NH_3 emission from a higher level: that of trends in domestic and foreign consumption of various foods produced in Canada.

The historical development of livestock and poultry production is toward larger farm operations with a greater use of confinement husbandry. Apart from boutique production of free-range swine and poultry, these sectors use barns exclusively, and the tendency is to larger barns often on relatively smaller land bases with feed and waste being transported from increasing distances. Similarly, lactating dairy cattle in Canada now rarely spend much time outdoors (Sheppard et al., 2011a,b), despite the bucolic image that pervades the public perspective. Importantly, the dairy and poultry sectors tend to be concentrated in regions in Canada that also have substantial human populations. The beef sector in Canada is more complex. Beef operations specializing in animal reproduction (i.e. production and rearing of calves) are referred to as cow-calf operations and occupy large areas of relatively unproductive land with permanent or long term forage cover and with little fertilizer or other crop inputs. These operations tend to be relatively small and widely dispersed across Canada with low animal densities, often located far from human population centres. Many weaned beef calves are raised in small herds on summer pasture or in small winter feedlots (called drylots) or, increasingly, winter pasture until the market warrants that they be shipped to larger concentrated feedlots to be fattened as rapidly as possible to market weight (Sheppard et al., 2015). The intermediary operations are often referred to as 'backgrounding' and the cattle are referred to as stockers. As the cow-calf and backgrounding operations are low-input, often using unfertilized forages of intermediate quality and continuous grazing, they have relatively low NH_3 emissions per unit area or per head. In striking contrast, typically large beef cattle finishing operations (turnover >200,000 head per year) produce higher protein feed and keep cattle in mostly open feedlots with wind breaks but no roofs (Sheppard and Bittman, 2012). Emissions of ammoniacal N from these finishing operations can be nearly quantitative: up to 90% of the ammoniacal N from manure of finisher cattle is emitted to the atmosphere during the warm season because fresh urine is continually deposited on the surface of the bedding packs with little capacity to adsorb NH_3 (Sheppard and Bittman, 2012), often leaving relatively little ammoniacal-N in the manure that is produced (e.g., Mooleki et al., 2004). In confinement,

Table 1
Calculation sequence to estimate NH_3 emission per unit of food, protein, calorie or dollar value, and then per person, for livestock food products.

Quantity		Meat	Milk	Eggs
Numbers of animals on farms (Census of Agriculture)	A	Number of occupied animal places differentiating young, breeders and production animals	Number of lactating and dry cows and associated calves and heifers	Number of laying hens
Numbers of slaughter animals exported live	B	Number of slaughter animals exported live	Not relevant	→
Feed intake (dry matter intake per animal)	C	From livestock emission models (Sheppard et al., 2010b)	→	→
Feed composition (fraction)	D	Fraction of feed from grain, whole corn, straw and forage (from farm survey)	Fraction of feed from grain, whole corn, straw and forage	Assumed to be fully grain
Emission attribution to feed material (fraction)	E	95% of emission from feed grain, 10% for straw, 100% for forages and corn	95% of emission from grain, 10% for straw, 100% for forages and corn	95% of emissions from grain
Emissions per unit of harvested crop	F	From fertilizer model (Sheppard et al., 2010b)	→	→
Emission from feed production per animal place	G	C*D*E*F	→	→
Emission from excretion per animal place	H	From livestock emission models (Sheppard and Bittman, 2013 and references therein)	→	→
Total emission per head	I	G + H	→	→
Total emission for Canadian produced animal based food	J	(A−B)*I	A*I	→
Food production per animal	K	Carcass weight	Litres per lactation	Eggs per cycle
Production frequency per animal place (fraction)	L	Fraction of herd/flock slaughtered per year in Canada, >1 for poultry and grower pigs to account for production cycles	Not relevant	→
Emission attribution to product (fraction)	M	Emissions of breeders and replacer young (excluding slaughter calves) attributed to slaughtered production animals.	Most of dairy emission including all cows, calves and heifers attributed to milk, about 3% attributed to meat	Most layer emissions attributed to eggs, about 7% attributed to meat
Total food (as carcass) production in Canada	N	(A−B)*K*L*M	→	→
Emission per unit of food (as carcass) produced	O	J/N	→	→
Conversion to other metrics	P	Per carcass, retail and as-consumed weight, protein, calorie, dollar	→	→
Protein intake per person	Q	For each food product (StatsCan)	→	→
Emission per person	R	P*Q where P is emission per unit of protein	→	→
Fate/source of food	S	Mass of production in terms of domestic use, export and import	→	→
Emissions related to imported and exported food	T	P*S where P is emission per unit of protein	→	→