Assessment of whether a limit value of 5 mg iodine per kg of complete feed ration (including 12 % water) will fulfil the requirements of ruminants for iodine

Advisory memorandum from DCA – Danish Centre for Food and Agriculture

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Data sheet

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Commissioned by:	Danish Veterinary and Food Administration
Date for request/submission:	01.04.2022/ 13.06.2022 (Danish version submitted 28.04.2022)
File no:	2022-0358740
Founding:	This memorandum has been prepared as part of the "Framework Agreement on the Provision of research-based Policy Support" between the Danish Ministry of Food, Agriculture and Fisheries (MFVM) and Aarhus University (AU) according to ID no. 22-H3-01 in the "Performance Agreement of Animal Production 2022-2025".
External comments:	No.
External contributions:	No.
Comments to the answer:	The original memorandum was submitted as a Danish version on the 28th of April 2022. A translated version was submitted from Danish Veterinary and Food Administration to Aarhus University on the 30th of May 2022. The Authors have used this version as template for the below English version, and made changes in accordance with the original Danish version.
To be cited as:	Nielsen MO, Rasmussen MD and Chassé E. 2022. Assessment of whether a limit value of 5 mg iodine per kg of complete feed ration (including 12 % water) will fulfil the requirements of ruminants for iodine. 9 pages. Advisory memorandum from DCA – Danish Centre for Food and Agriculture, Aarhus University, submitted: 13.06.2022.
Policy support from DCA:	Read more here https://dca.au.dk/raadgivning/

1 Background

The Danish Veterinary and Food Administration would like an assessment of the following:
1) Will Danish ruminants (milk cattle, beef cattle...) meet their physiological requirements for iodine if they can be given a maximum of 5 mg iodine/kg of complete feed ration (including 12 % water) throughout their life? The 5 mg/kg is the sum of the natural iodine content in feed materials and iodine from feed additives.
2) Teats of dairy cows may be exposed to quite high amounts of iodine disinfectants, and part of this iodine is absorbed as far as we are oriented via the skin (udder). Is this iodine-rich disinfectant likely to help meet the physiological needs of iodine in cattle?
The Danish Veterinary and Food Administration provides as the basis for the requested assessment:
The limits for iodine in feed for dairy cows have been revised downwards in the EU in 2005 from 10 mg/kg feed to 5 mg/kg feed, if iodine is given in the form of feed additives. However, it is currently possible for cattle to be assigned to higher levels of iodine via iodine-rich feed materials such as algae etc. if iodine is not simultaneously allocated in the form of feed additives.
The Commission is now considering that the 5 mg/kg feed limit for iodine should apply as a maximum limit, regardless of whether or not iodine is supplemented by additives. Iodine as an additive may be allocated in the following forms:
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:JOL_2015_137_R_0001&from=EN
(authors' remarks: the link does not work, but the permitted chemical forms are: calcium iodine anhydrous and potassium iodide).
The European Food Industry Organisation (FEFAC) considers that the Commission's proposal for a general maximum limit of 5 mg iodine/kg feed could seriously affect animal welfare, especially in ruminants.
Letter from FEFAC attached for information. Thus, it appears that FEFAC assumes that a future limit of 5 mg/kg may be below the physiological requirement of ruminants for iodine and that it cannot be ruled out that this limit will give rise to animal health and animal welfare concerns.
On this basis, there is a need for a professional memo that addresses questions 1) and 2) above.

2 Ruminants' need for iodine and contributions from the feed and udder disinfectants to meet the physiological requirements for iodine

Iodine is an essential nutrient for animals and humans. The main biological function is as a building block in the synthesis of thyroid hormones that are formed in the thyroid gland. Both over- and under-supply with iodine can give rise to thyroid related diseases and metabolic/developmental disorders. Before Denmark started with addition of iodine to livestock feed, iodine deficiency in humans was commonly observed, especially in areas with sandy soils, where iodine contents in soil and groundwater are low (Laurberg at al., 2006).

It has been shown across several scientific studies (reviewed by Flachowsky et al., 2016) that the concentration of iodine in milk from dairy cows increases linearly with an increasing iodine content in the feed ration from 0-5 mg iodine/kg dry matter. Humans are significantly less tolerant to high iodine intakes than cattle (Flachowsky et al., 2914). One of the most important sources of iodine for humans is milk (Flachowsky et al., 2014), and in Norway it is estimated that about 60 % of iodine intake in the population comes from consumption of milk products (Trøan et al., 2015). The iodine content of milk in industrialised countries increases with increasing administration of iodine in the feed ration to dairy cows, and it varies between 33 to 534 µg/litre milk with typical values between 100 to 300 µg/litre (van der Reijden et al., 2017). In Denmark, the recommended daily intake of iodine is 90, 150, 120 and 150 µg iodine for 2-5 year old children, 6-9 year old children, 10-13 year old children and older children and adults (NNR, 2012). With the prospect that iodine-rich feed materials, such as marine macroalgae, will be used to an increasing extent in livestock production in the future, the European Commission wishes to set maximum levels for iodine in feed for ruminants of 5 mg/kg total feed ration (including 12 % water), i.e. including any type of feed additives.

2.1 Will Danish ruminants meet their physiological needs for iodine throughout life by an allocation of max. 5 mg iodine/kg complete feed ration (including 12 % water)?

In Denmark, as in the rest of the EU, we have operated with a maximum limit in feed for ruminants of 5 mg iodine/kg complete feed ration (with 12 % moisture content) since 2015. This level is significantly above estimates of both the physiological requirements of ruminants and the Danish recommendations, as shown in Table 1.

2.1.1 The need for iodine and risks of development of iodine deficiency in ruminants

Iodine is effectively absorbed from the intestine in cattle with 70-90 % efficiency, and the main excretory pathways from the body are via urine and milk, where excretion in both cases increases with increasing intake of iodine from the feed (Miller, 1975, Miller et al., 1975). The greatest risk of under-supply with iodine is seen in grazing animals that are not given complementary feed and grazing iodine-poor soils (Jensen et al., 2019, Knowles and Grace, 2015), i.e. far from coastal areas.

Symptoms of iodine deficiency are predominantly observed in newborn ruminants of mothers, who have been under-supplied with iodine during pregnancy, i.e. the risk of iodine deficiency is greatest in the case of under-supply of pregnant females among small ruminants, which, unlike cattle, are typically pregnant with more than one foetus. It is estimated that sheep (which carry multiple foetuses) at the end of pregnancy should be given 300 µg iodine/day to prevent goiter in the newborn foetuses (Statham, 1974), which can be covered by only 60 g of feed containing 5 mg/kg, i.e. well below normal feed uptake in pregnant sheep. Administration of iodine for pregnant dairy cows in addition to the recommended minimum requirements (see Table 1) was unnecessary to ensure adequate iodine status in newborn calves (Conneely et al., 2014). The availability of iodine present in the feed decreases, if the feed ration contains so-called goitrogenic substances that inhibit the absorption of iodine in the thyroid gland. Feeding these substances will therefore also increase the animal's requirement for iodine in the feed.

Goitrogens occur in cruciferous plants, such as rapeseed. Rapeseed products are increasingly used as complementary feed for ruminants in DK, which is why DK has a higher recommendation for iodine administration to dairy cattle (1.0 mg/kg feed), since rapeseed products are typically included in their ration, as compared to rations for other categories of cattle (0.5 mg/kg feed) (Volden, 2011). However, this recommendation is still below the 5 mg/kg complete feed ration.

In humans, nitrate has been shown to have a goitrogenic effect (Mukhopadhyay et al., 2005, Tajtáková et al., 2006). There is no scientific evidence available to evaluate, whether this is a factor, which should be taken into account, if nitrate is to be used on a larger scale as an instrument to reduce methane emissions from cattle.

Table 1: Minimum requirement of ruminants for iodine, and Danish recommendations for daily dietary administration of iodine to meet the requirements of different animal groups

Animal group	Minimum requirement for iodine** mg/kg of feed dry matter	Danish recommendations for cattle for iodine*** mg/kg feed dry matter
Dairy cattle:		
• Lactating	0.45	1.0
• Other cattle	0.33	0.5
Beef cattle:		
• All types	0.5	0.5
Sheep*:		
• Lamb	0.48-0.49	
• Gestation	0.47-0.53	
• Milk producing	0.77-0.83	
Goats*:		
The Kid	0.48-0.50	
• Gestation	0.50	
• Milk producing	0.80	

* Possible variation is across age, growth rate, body weight, stage of gestation, milk yield, and for sheep and goats litter size.

** Dairy cattle: NRC (2001), beef cattle: NRC (2000), sheep and goats: NRC (2007)

*** Volden (2011). Danish recommendations for iodine for dairy cattle are above NRC's, as it is common in Denmark to use goitrogenic feeds (rapeseed products) in dairy rations.

2.1.2 Other conditions

In a letter dated 22.11.2021 to the European Commission's Unit for Animal Nutrition, the industry organisation FEFAC expresses concern that by setting a general upper-limit for iodine content in the entire feed ration (including all feed additives such as vitamin mineral mixtures and other feed additives), producers will be discouraged from using innovative feed materials, which otherwise would be beneficial from a circular bioeconomy perspective, and in order to inhibit the formation of methane during forestomach fermentation of feed in ruminants.

This is, in particular, a relevant concern in relation to marine macroalgae (seaweed), among which some species are known to absorb and accumulate iodine from the sea water they grow in, and feeding such algae to dairy cattle may increase the iodine content in the milk (Antaya et al., 2015). However, many of these algae species also have a relatively low digestibility (Tayyab et al., 2016). If they are used in the future, as feed materials on a larger scale, then it will therefore probably only be for selected groups of animals within a herd, for example young animals and cows in late lactation, which do not have the same requirements for a high digestibility of the total ration as high-producing dairy cows in early lactation. Thus, milk from these lower-producing cows would become diluted with milk from high-producing cows that are not given the iodine-rich feed materials.

It could therefore be considered in the future to define upper-limits for iodine content in the milk delivered from the herd as a whole, so that the regulation would be based on maximum levels of iodine in food materials intended for human consumption, rather than providing fixed maximum-levels for feed rations. This could be relevant when new single feed materials/additives with high iodine content are expected to be consumed skewedly within a herd. At a maximum level for iodine content in milk of, for example, 300 or 400 µg/kg, a 2-5 year old child would have to drink more than 3 or 2.25 deciliters/day, respectively, to exceed the recommended daily intake of iodine.

In non-milk-producing cattle, the main route of excretion of iodine is via urine. In beef cattle, increased levels of iodine in feed will accumulate particularly in the thyroid gland, but increased iodine concentrations have also been seen in muscle tissue and especially in the liver, though in significantly lower concentrations than in milk (Flachowsky 2007).

2.1.3 Conclusion

It can be concluded that there is no evidence to indicate that the need for iodine for ruminants will not be covered throughout life at an upper-limit for iodine content in the feed of 5 mg/kg of complete feed ration (i.e. the total feed ration including 12 % water). However, it should be investigated, whether this would also apply in the case of widespread use of dietary nitrate supplementation to inhibit methane emission from ruminants, due to a possible goitrogenic effect of nitrate. With a view to ensure an appropriately low iodine content in animal-derived foods for human consumption, it is recommended to consider, whether it would be more appropriate to base regulation on maximum levels of iodine in the product for human consumption (milk delivered ab herd) rather than define upper-limits for total iodine content of the feed ration across animal groups.

2.2 Can iodine-rich udder disinfectants help meet the physiological needs of iodine in cattle?

Iodine is used as a disinfectant of cows' teats to a large extent during milking. The iodine is bound in a complex (iodophore) in the udder disinfectants and iodine is released into an equilibrium from the iodine, so that there is a constant amount of freely active iodine. The disinfectant is applied either by dipping the teats in a cup or by spraying, which can be done immediately before milking or just after milking. When used before milking, the teats must be wiped before applying the milking unit. When used after milking, the excess of the teat dip drips off and the remaining part dries up.

Iodine can penetrate the skin and increase iodine content in milk and plasma (Conrad & Hemken, 1978). Conrad and Hemken (1978) conclude that the main reason for an increase in the iodine content of the milk after milking is due to absorption through the skin rather than a contamination from the surface of the teats. Rasmussen et al. (1991) conclude on the basis of an experiment with iodine dipping of teats prior to milking that an increase in the iodine content of the milk is primarily due to contamination from the surface of the teats, since thorough drying of the teats before milking could eliminate the contamination. Using spray instead of udder disinfection with a cup increased the milk's iodine content by about 120 % (Borucki Castro et al., 2012). The authors concluded that this is because the disinfectant by spray is also applied to parts of the udder base and absorption of iodine can be done from a larger skin surface if the iodine is not wiped again when preparing for milking.

Post-milking teat dipping with a 1 % iodine solution did not increase the iodine content of the milk (Borucki Castro et al., 2012).

The concentration of iodine is higher in milk than in plasma due to active transport mechanisms in the udder that transmit iodine from blood to milk (Borucki Castro et al., 2012). The milk's iodine content increases linearly with iodine increase in feed (Borucki Castro et al., 2012). With increased iodine distribution through feed, the concentration of iodine in particular urine increases within a few days, and to a lesser extent in milk and least in blood plasma (Ahvanooei et al., 2021). In the same experiment, Ahvanooei et al. (2021) used a 3 % iodine solution for teat dipping, which significantly increased the iodine content of the milk by dipping after milking (3-folded) but not by dipping before milking. The iodine content of urine increased by about 60 % by teat dipping after milking, but the iodine content in blood plasma was not affected by udder disinfection methods. This suggests that udder disinfectants (eg. spraying) cannot significantly supplement the animal's need for iodine, but high concentrations of iodine in udder disinfection agents can increase the milk content of iodine.

In Denmark, udder disinfection agents are typically used with a content of 1500-3000 ppm (0.15-0.3 %), i.e. only 5-10 % of the concentration used in the Ahvanooei et al (2021) trial. Manufacturers indicate a typical use of 4 ml of teat dipping agent per cow per milking. For two daily assignments of a solution with 0.25 % iodine, daily dipping/spraying will apply: 8 ml x 1.05 g/ml x 0.0025 x 1 000 mg/g = 20 mg/day.

Part of this iodine will drip off, and the remainder will mainly be excreted via urine and to a lesser extent via milk without significant impact on the cow's iodine status in general.

2.2.1 Conclusion

It can therefore be concluded that teat dipping and spraying when properly used will only be able to meet the physiological needs of the cow for iodine to a minimum extent. It cannot be excluded that high iodine doses in the feed in combination with improper use of teat dipping or spray may bring the total iodine content of the milk to a level that can be considered critically high for vulnerable population groups (small children).

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