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Brief of requirements of the dairy cow

Kracht van Koeien/ Cow Power

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ISO 9001 certification by DNV emphasizes our quality level. All our research projects are subject to the General Conditions of the Animal Sciences Group, which have been filed with the District Court Zwolle.

Abstract
This report lists the brief of requirements of the dairy cow, based on her needs (also listed). The BoR indicates the actor's needs with regards to the animal husbandry system. BoR of the main actors are incorporated in the re-design of a dairy husbandry system in the project Cow Power

Keywords
Brief of requirements, needs, dairy cow, dairy husbandry, system innovation, re-design, designs for system innovation, sustainable husbandry

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Preface

More and more livestock farmers and other interested parties have been cooperating towards sustainable livestock husbandry. Since 2001, the “Designs for System Innovation” programme in the Netherlands has been working together with livestock farmers, the business world and policymakers to design concepts for sustainable livestock husbandry. Their aim is to serve as stepping stones: once implemented, they will significantly contribute to sustainable husbandry.

In the project Cow Power (Kracht van Koeien) we work on innovative concepts of a totally new and different dairy husbandry. In 2009 these design will be presented to the Dutch minister of agriculture. The concepts of sustainable livestock husbandry are not blueprints but stepping stones. By now several initiatives have started that support the ambition of the project and the long-term vision of the concepts. New networks of different actor evolve, the networks adapt the concepts to their own situation and so make the leap towards sustainability.

Cow Power is part of a programme called “Designs for System Innovation”. In this programme, researchers work together with livestock farmers, the business world and policymakers on a range of concepts for sustainable livestock husbandry. Once implemented in the farming practice, these concepts will bring about a more sustainable system of livestock husbandry. Concepts for System Innovation: stepping stones towards sustainable livestock husbandry.

Cow Power is a project of the Animal Sciences Group of Wageningen UR in the Netherlands for the Dutch Ministry of Agriculture within the research programme “Towards Sustainability in Production and Transition” (Verduurzaming Productie en Transitie; BO-07-009-005).

Voorwoord

Een duurzame veehouderij. Een houderij waarin de behoeften van dier, milieu, consument en ondernemer verenigd zijn. Dit is voor veehouders een praktisch zoektocht, voor het ministerie van LNV een uitdagende ambitie. Het vraagt om een omslag in denken en doen; een systeeminnovatie. De Animal Sciences Group van Wageningen UR werkt met veehouders, bedrijfsleven en beleidsmakers aan Ontwerpen voor Systeeminnovatie. Deze ontwerpen openen nieuwe kansen om sprongen in duurzaamheid te maken.

In het project Kracht van Koeien wordt gewerkt aan innovatieve ontwerpen van een fundamenteel andere melkveehouderij. Begin 2009 zullen deze Ontwerpen voor Systeeminnovatie aan de minister worden aangeboden. In 2008 zijn ook diverse initiatieven gestart die de ontwerpen ondersteunen. Nieuwe netwerken vormen zich die met de ontwerpen aan de slag willen, die het vertalen naar de eigen situatie en het in de praktijk verder ontwikkelen.

Kracht van Koeien is onderdeel van het programma Ontwerpen voor Systeeminnovatie. In dit programma werken onderzoekers, samen met veehouders, bedrijfsleven en beleidsmakers aan een serie ontwerpen voor duurzame veehouderij. Eenmaal in de praktijk gebracht leiden deze ontwerpen tot een duurzamer veehouderijsysteem. Ontwerpen voor Systeeminnovatie: springplank naar een duurzame veehouderij.

Kracht van Koeien wordt uitgevoerd in opdracht van het Ministerie van Landbouw, Natuur en Voedselkwaliteit (LNV) in het kader van het beleidsondersteunend onderzoeksprogramma Verduurzaming Productie en Transitie. Dit rapport is onderdeel en product van het project Kracht van Koeien (BO-07-009-005).

Table of contents

1 Introduction

In this report we present the Brief of Requirements (BoR) of the dairy cow. This BoR is part of the project Cow Power (in Dutch: Kracht van Koeien) (Bos, Cornelissen, and Groot Koerkamp 2009). In Cow Power, BoR's for the four major actors in the animal husbandry system were formulated: the animal (dairy cow), the entrepreneur (dairy farmer), the environment and the citizen / consumer. BoR's are an essential part of the RIO approach and the Designs for System Innovation (Ontwerpen voor Systeeminnovatie)[1].

The BoR of the dairy cow is based on the ethological needs of the cow. The requirements are stated in a solution free manner as to create opportunity for creative, out-of-the-box solutions and designs. The requirements of the four BoR's that are developed in the project Cow Power together constitute the conditions the new design concepts have to meet. Besides this, BoR's serve to evaluate design concepts afterwards. BoR's are based on scientific literature, practical and expert knowledge.

[1] More information can be found on http://www.duurzameveehouderij.wur.nl

2 Lay-out and set-up of the Brief of Requirements

The description of Animal welfare by Bracke *et al.* (1999) is taken as the starting point of the Brief of Requirements: ‘Animal welfare is the quality of life as perceived by the animals themselves’. Welfare is a function of the animal’s needs, which relate to the animal’s biological control systems that have developed in the course of evolution to deal with a variable environment. Biological needs include the need for 1) food, 2) water, 3) rest, 4) social contact, 5) reproduction-related needs (such as the need for a mate, mate and maternal behaviour), 6) movement, 7) exploration, (including foraging and play), 8) body care, 9) elimination (voiding of faeces and urine), 10) thermoregulation, 11) respiration, 12) health, and 13) safety (Anonymous 2001). These needs can be categorized as behavioural and physiological needs. All needs, however, have an environment-based aspect, a behavioural aspect, a physiological dimension and an emotional dimension (Bracke *et al.*, 2008).

The BoR of the dairy cow is based on these biological needs of the cow. The BoR indicates the requirements of the cow with regards to her environment, which is made up of the ‘technological’, ‘natural’ and ‘social components’ as well as the ‘management of the environment’ by the farmer. The requirements are stated in a solution-free manner as to create opportunity for creative, out-of-the-box solutions and designs.

Most of the requirements in the BoR are based on and apply to Holstein Frisian cows in a milk production system, which are normally dehorned and highly productive. As such, we do not formulate any requirements of the cow with regards to her genetic design. Rather, genetic design is considered a fact. But, the current genotype and phenotype of Holstein Frisian cows brings along special characteristics with regard to e.g. milk yield (high), utter size (large), body measures (large), metabolic requirements (high feed intake) and reproduction. This poses requirements to the environment that differ from cows that still live under more natural conditions.

The BoR is divided into several sections based on the requirements of the cow for specific issues of the husbandry system. Requirements are quantified, references and type of reference are given for each requirement.

Whilst scientific literature about the welfare of cows mainly deals with assessments of current systems and its elements (and results in statements like ‘the cow prefers pen of size x over pens of size y’, we sought for ‘solution-free’ statements. This is rarely the topic of scientific studies and therefore such statements are seldom found in literature. For the formulation of requirements in the BoR, a group of experts including ethologists reflected upon the references at hand in order to obtain a precise statement about the preferences of the dairy cow with respect to the condition of her environment. As a result, not all references originate from peer-reviewed scientific articles. In addition handbooks, practical and expert knowledge were used. The type of reference is given for each requirement with a code; 1 = Based on peer-reviewed scientific publications; 2 = Based on handbooks or originating from practical, expert knowledge; and 3 = Based on both scientific and expert knowledge.

The level or numerical value for each requirement in the BoR is not the bare minimum to which a cow might be able to adapt to. The requirements represent the preferred level of the cow. Fulfilment of the requirements will enable dairy cows to practice their behaviour undisturbed and without unnecessary stress, aggression and other negative behavioural or physiological discomfort. In addition, it enables natural behaviour and gives the best possible chances for good welfare.

Spatial requirements can be interpreted in two ways. First, there is the individual (or personal) space of the animal. This results in the area that should be given to each animal. Each animal needs a certain amount of personal space. When shade or shelter is sought this space can be smaller as cows decrease distance between them (Johnson et al, 2007). Second, there is the home range where the herd remains. This results in other requirements, like the floor, positioning of drinking or feeding places (lay-out) and other environmental aspects (sound, etc)

When resources like space, food or water is limited, cows needs to compete for these resources. As a result individuals will show agonistic behaviour (Boe and Faerevik, 2003; DeVries *et al.*, 2004; Phillips, 2002). Agonistic behaviour impairs the cow's welfare, especially that of subordinate cows. To minimize agonistic behaviour, enough space should be provided for and resting, feeding and drinking places should be present for all cows. Furthermore, cows should have the freedom to move within the herd and within the area, so they can avoid conflict with higher ranked cows and so that they can be near friendly herd members.

3 The Needs of the dairy cow

3.1 Needs

The following changes were made to the list of biological need by Anonymous (2001) rest (no. 3) also includes rumination, reproduction related needs (no. 5) are presented separately as sexual behaviour and maternal behaviour (no. 5 and 6 in list below), movement (no. 6) is presented as locomotion (no. 7 in list below), exploration (7) and play are presented separately (no. 8 and 9 in list below), and elimination (9) was left out as this need does not pose specific distinctive requirements to the environment directly (in addition to other require-ments). For each requirement we indicated to which needs it is related. Needs are coded with a two letter code:

1. Fo = feed and foraging
2. Wa = water intake
3. RR = rest and rumination
4. So = social behaviour
5. Se = sexual behaviour
6. Ma = maternal behaviour
7. Lo = locomotion
8. Ex = exploration
9. Pl = play
10. Bo = body care and allogrooming
11. Th = thermoregulation
12. Re = respiration
13. He = health
14. Sa = safety

An extensive description of these needs is given below, the references to literature are given in paragraph 3.4. Each need is described in the title, followed by the typical behaviour and / or physiological process of a cow to fulfil this need. The needs health and safety form an exception: to maintain a good health and safety condition a range of behaviours and physiological processes are involved.

1) Need for satiety with food - feed intake
Feed has to be of the correct quality, quantity and structure to fulfil the need for food. If not, cattle can for example develop stereotypies, e.g. tongue rolling (Redbo *et al.*, 1996), rumen problems, acidosis (Mertens, 1997; Zebeli *et al.*, 2006; Webster, 1994; SubcommitteeOnDairyCattleNutrition, 2001), and lameness (Webster, 1994; Blowey, 2005; Fraser and Broom, 1997). Each cow has a different nutrient demand, which depends on their age, lactation stage, and breed (SubcommitteeOnDairyCattleNutrition, 2001; Taylor and Field, 2004; Cammell *et al.*, 2000). Energy and nutrients should be predicted for each cow individually and therefore, the provision of food should also be individual (Hollander *et al.*, 2005). This requires at least one feeding place for each cow, with the correct dimensions, to give them the opportunity to synchronize their feeding behaviour (CIGR, 1994; DeVries *et al.*, 2004; DeVries and Von Keyserlingk, 2006; Olofsson and Wiktorsson, 2001). The behaviour of cattle follow a diurnal rhythm, especially concerning feeding which occurs mostly during dusk and dawn (Albright and Arave, 1997; DeVries *et al.*, 2003; Durst *et al.*, 1993; Ouweltjes *et al.*, 2003; Phillips, 2002; Shabi *et al.*, 2005). Additional information on grazing behaviour in relation to the requirement of access to pasture is given in paragraph 3.2.

2) Need for satiety with water - water intake
Water availability is an important topic within cattle housing (Eastridge, 2006). Clean drinking water in correct drinking facilities needs to be provided on an ad libitum basis. If, for example, the water is visibly contaminated with faeces the cows will avoid it (Ouweltjes *et al.*, 2003; Willms *et al.*, 2002). Furthermore, the frequency of aggression will be high if there are not enough drinking places present (Albright and Arave, 1997).

3) Need to recover - Rest
The ideal resting area for a cow is a pasture (>360 m^2/cow) with dry areas and without loose rocks or other hindering objects (Ketelaar-De Lauwere et al. 2000; Phillips 2002). For cows housed indoor there should be more than one resting place per cow to ensure that synchronised lying behaviour is possible, and to ensure that subordinate cows can avoid dominant cows if necessary (Berry, 2001; CIGR, 1994; Fraser and Broom, 1997). Bedding material has to be of the right quality, e.g. deep straw or sand bed, to prevent injuries (Berry, 2001; Bierma *et al.*, 2006; Blowey, 2005). During night-time hours the light intensity has to be low, but not completely dark, to ensure a normal diurnal rhythm (Albright and Arave, 1997).

4) Need for social interaction - social contact
Cows are herd animals and, as mentioned above, perform social behaviours. There is a hierarchy among cows, with low, middle and high ranking animals. Low ranking cows regularly avoid high ranking cows. If not enough space is provided, the frequency of agonistic behaviours will be high. A herd should not contain too many animals to ensure that every cow knows its rank within the hierarchy (Bøe and Færevik, 2003; Menke *et al.*, 1999; Ouweltjes *et al.*, 2003; Rind and Phillips, 1999). Furthermore, if new animals have to be introduced to the herd this needs to be done in small groups (Albright and Arave, 1997; Morrow-Tesch, 2001).

5) Need for sexual behaviour
Sexual behaviour is a need when cows are in oestrus. In conventional housing systems cows normally get artificially inseminated, without the intervention of an actual bull. Cows mount each other when they are in oestrous. To perform this behaviour cows need to have sufficient (free) space, a non-slippery floor (to prevent lameness), and herd mates (Phillips, 2002; Albright and Arave, 1997; Blowey, 2005; Anonymous, 2001).

6) Need for maternal behaviour
Dairy cows have offspring every year to ensure milk production. Besides purely producing milk, the cow has the need to perform maternal behaviour. Just before calving the cow has the urge to separate herself from the herd (Fraser and Broom, 1997; Hopster *et al.*, 1995). A clean maternity pen, with a deep (straw) bedding, should be available for this purpose (CIGR, 1994; Webster, 1993; Albright and Arave, 1997). Several hours after birth, a bond between mother and calf has been established (Hopster *et al.*, 1995; Jensen, 2003). In nature, a calf is weaned at the age of 8 to 12 months (Flower and Weary, 2001). Thus, separating mother and calf before natural weaning causes stress in both calf and cow (Flower and Weary, 2001; Marchant-Forde *et al.*, 2002; Loberg, 2007). Nowadays, a dairy cow produces more milk than one calf is able to consume. Therefore, the cow has to be milked by a machine in addition to calf suckling. Individual quarter milking can help to prevent mastitis (Weiss, 2004).

7) Need for locomotion – move
Locomotion is a need to fulfil most other needs, for example, a cow needs to walk to a feeding or drinking place, and to explore its environment. Freedom to have the opportunity to walk towards a desired site within the housing is necessary. This requires a sufficient and safe floor type to prevent, for instance, slipping; the friction coefficient has to be between 0.4 and 0.5, the floor should not be too rough, and the hardness of the floor has to be acceptable (Anonymous, 2001; Ouweltjes *et al.*, 2003; Phillips and Morris, 2001; Phillips, 2001; Telezhenko *et al.*, 2007). Another point of consideration is the light intensity within the housing of the cows. Cows walk more carefully (they increase their stepping rate and reduce their step length) when their environment is too dark (Phillips and Morris, 2001; Phillips *et al.*, 2000).

8) Need for exploration - explore
Cows are inquisitive animals that will explore a new surrounding, object, or person by sniffing, licking, and if possible by eating it (Herskin *et al.*, 2004; Webster, 1993). Therefore, they should have the opportunity to behave freely and explore these novelties if they intend to do so.

9) Need for play behaviour - play
Play behaviour is common in calves (Bøe and Færevik, 2003; Jensen and Kyhn, 2000), but is still present in adult cattle as well, and motivation for playing builds up with time of confinement (Loberg *et al.*, 2004). Cattle perform play behaviour mainly at mid morning and mid afternoon and increases with light intensity (Vitale *et al.*, 1986 in Philips, 2002). A prerequisite for play behaviour is a good floor type (concerning friction, hardness, roughness; see "locomotion") and of course cows should have the freedom to display this behaviour.

10) Need for body care – lick & (allo)groom
Body care is important to ensure a clean and healthy skin. The body areas that they cannot reach are often groomed by other cows (Anonymous 2001) or they use objects like trees (Kohari *et al.*, 2007). However, tied cows cannot sufficiently groom themselves (Loberg *et al.*, 2004) and certainly not groom other cows. Since allogrooming is also an important behaviour to strengthen social cohesiveness (Albright and Arave, 1997; Simonsen, 1979) cows should not be thwarted to perform this behaviour.

11) Need for thermal comfort – control body temperature (thermoregulation)
A cow has a body temperature of ca. 38.2℃ which th e cow tries to maintain under every environmental circumstance (Webster, 1993). When the Temperature Humidity Index exceeds 71 (e.g. 30℃ and 45% relative humidity = THI of 78) the cow experiences heat stress (Fang, 2003; Armstrong, 1994; Ingraham *et al.*, 1976). To alleviate heat stress certain measures can be taken by, for example, using fans (Collier *et al.*, 2006; Frazzi *et al.*, 2000; Hillman *et al.*, 2005) and providing sufficient shade (Collier *et al.*, 2006; Kendall *et al.*, 2006; Valtorta *et al.*, 1997). Cold stress, however, can also occur if the ambient temperature is low and/or when there are harsh wind and rain conditions. Therefore, shelter has to be provided (Fraser and Broom, 1997).

12) Need for gas exchange - respire
Cattle have an intrinsic need for respiration. The surrounding air has to be of the correct composition to prevent the cows from suffering of respiratory diseases (Ouweltjes *et al.*, 2003). Therefore, a housing system needs to have a high-quality ventilation system, preferably a combined natural and mechanical one, to make sure that the surrounding air will not saturate with ammonia, carbon dioxide, and hydrogen sulphide, and to regulate indoor temperature and humidity level (Ouweltjes *et al.*, 2003; Smits *et al.*, 1993; Collier *et al.*, 2006; CIGR, 1994).

13) Need for health
Of course, cows also have a need for good health. To ensure good health the environment has to be clean and hygienic (Anonymous, 2001; Berry, 2001; Bierma *et al.*, 2006; Phillips, 2002) and several disease prevention methods need to be in place, e.g. disinfecting footbaths (Somers *et al.*, 2004; Blowey, 2005), hoof trimming (Espejo and Endres, 2007; Phillips *et al.*, 2000), and dipping and spraying udders after milking (Blanken *et al.*, 2006). Furthermore interventions like dehorning (Laden *et al.*, 1985), tail docking (Morrow-Tesch, 2001; Grassi de, 2001) and ear tagging need to be absent. In paragraph 3.3, additional information is given on the need for health, including statements why no specific requirements for health are listed in the BoR.

14) Need for safety
A cow needs to feel safe and secure in its surrounding to prevent acute and chronic stress. This requires a predictable environment (Bruckmaier, 2005; Grandin, 2001), a low noise level in the milking parlour (Arnold *et al.*, 2007; Sambraus and Hecker, 1985), and gentle handlers (Bierma *et al.*, 2006; Breuer *et al.*, 2003), and no negative conditioners (e.g. electric cow trainer) (Hultgren, 1991; CIGR, 1994; Oltenacu *et al.*, 1998), and stray electricity (Hultgren, 1990ab).

3.2 Background information on grazing behaviour and pasture use

An important issue in the Brief of Requirements is the question whether cows must have access to pasture and be able to graze in a natural way. Grazing itself is not in the list of the needs and as such is not considered to be a fundamental need of the cow, whereas feed intake is essential to reach a state of satisfaction and foraging the natural corresponding behaviour is of cows. Foraging comprises of searching, selecting, picking, biting, chewing, swallowing, regurgitating and ruminating the feed. One viewpoint is that all these elements of foraging are important for cows, however from another viewpoint it can be stated that cows are very flexible in their foraging behaviour – the elasticity of grazing is high as compared to others types of feed intake. Cows can arrange their feed intake in situations without grazing very well (but indeed having access to hay, silage grass and maize, and concentrates at feeding places in a cow house) without negative effects on welfare. Moreover, the nutritional requirements of current cows with a high milk yield can not be covered with intake of grass from pasture alone. Literature on the effects on cows of grazing versus indoor housing and feeding does not give an indisputable answer on the requirement of permanent access to pasture and grass. Mainly because the conditions between outdoor (pasture) and indoor are different with regard to several attributes or elements like space per cow, floor condition, freedom of movement, lying area and aerial climate. The term grazing is often used as a synonym for being outdoors (i.e. in an area with a lot of space and soft floor and bedding). In this respect it is a reasonable existing solution to fulfil a number of requirements that cows demand (see the BoR), and that are marginally or not fulfilled in existing cow houses. Consequently grazing is often seen as essential and positive as compared to or additional to indoor housing. The following quote from Anonymous *et al.* (2001) illustrates this: "grazing is known to benefit claw health (less severe disorders and better recovery) and to reduce stereotypies and aggression in the herd." Stereotypies are never performed when cattle are at pasture and have never been observed in animals in the wild (Phillips, 2002). The most distinguishing element between grazing in a pasture and feed supply in a cow house is the act of grasping fresh grass and pinching it off between the incisors and dental pad by the cow. So far, literature and practical experiences do not give a clear answer whether this element of foraging and rumination is really preferred by the cow.

The absence of the application of interventions like dehorning, number branding on the skin and conditioners are specifically mentioned in the BoR. These treatments are not part of or fulfil the needs of the cow. Moreover, the BoR normally specifies what the cows wants (positively stated), not what she doesn't want or need. The Cowel model (Ursinus *et al.*, 2008) showed that these negative interventions result in negative effects on the cow.

3.3 The special place of health in the BoR

Health is evidently important for the dairy cow, and animals in general. It is therefore quite understandable that health is often categorized as a basic animal need, see for instance (Anonymous, 2001). However, in the strict sense of needs as proposed by (Bracke *et al.*, 1999) health cannot be easily equalled to other needs, since needs are directly related to some internal motivational state of the animal, for instance to act and react to reach or maintain a certain physiological state (e.g. satiety, no thirst, carbon dioxide concentration in blood) or perform a certain behaviour (move, social interaction, sexual behaviour). Something can be classified as a need, as long as there is an internal motivation to fulfil it. It is from this point of view of the concept of needs, that we derived the requirements in this BoR.

Within this frame of thinking, health is of a different category. No direct physiological processes, behaviour or specific internal motivational states of cows are known that are directly related to maintain a certain status of health. It is mainly the immune system that is directly involved, both the innate and the adaptive subsystem. The fulfilment of a lot of other needs will however contribute directly or indirectly to health: from feeding and drinking to allogrooming and movement.

> *Thus, health is not a need in itself. Health is the state of the animal resulting from the challenges and perturburations in and from the internal and external world of the cow and the extent to which she can cope herewith by means of the functioning of her organ systems.*

A second reason to be especially scrupulous about health and health requirements in this BoR is the fact that external interests easily interfere with interests of the cow herself. Other parties (e.g. consumers, society, governments) may require health for different, but related goals (e.g. food safety, human health, trade, or eradication) at higher system levels (e.g. herd, farm, national, or EU). In daily practice of dairy husbandry these requirements are mixed with the requirements of the cow herself. In a BoR for the dairy cow, however, we want to limit the requirements to those that are directly related to the cow herself, and not inspired by other, external reasons.

Thirdly, the question of the ideal level of health for cows (and the corresponding requirements) is not trivial at all. The superficial answer would probably be the absence of diseases and the absence of contact with pathogens causing these. But this answer is not as straightforward as it seems. A) these requirements would strongly diverge from natural circumstances, in which pathogens, disease and impaired health are and have been part of life. Of course, it can be argued that domestication and captivity also entails human responsibilities regarding the animal that exceed these natural circumstances. But requirements like absence of pathogens and disease have not been part of the natural selection environment of the cow before domestication. B) these requirements are virtually impossible to achieve, at least practically. And even if we would be able to perfectly isolate cows from their environment, the result would very likely conflict with other requirements. C) one may even question whether the complete absence of pathogens would be in the interest of the cow, if we strive for the absence of disease. Mechanisms to cope with diseases have evolved around the constant presence of pathogens, and the acquired immune system is dependent on a certain level of contact with them for its proper functioning. Thus, a requirement of the absolute absence of contact with pathogens cannot be said to be an inherent requirement of the cow's physiology. The absence of disease could be stated as a general ideal, but as a requirement it would most probably never be met.

It is nevertheless clear that *impaired health* may lead to suffering, which in its turn is absolutely relevant for animal welfare. For instance, treatments that reduce pathogens in and on the cow (for instance by spraying udders or a claw bath) may be necessary for animal welfare in current husbandry systems, although the requirement of low pathogen levels can not be related to a need *stricto sensu*. Based on the same reasoning we did add requirements with regard to the absence of treatments as tail docking and dehorning.

We therefore conclude that *requirements* regarding health should be added to the BoR of the Dairy Cow, *as far as they are necessary to prevent serious and/or chronic suffering*. Next to this and the requirements based on the biological needs, we might have to add a number of general conditions that ensure the proper functioning of the cow's innate and adaptive immune system mechanisms that fight external threats in order to keep herself healthy or to cope with decreased health.

We need to make explicit what we mean with health, since this is not as self evident as it seems. Even in human medicine and health care, a precise definition is lacking. The WHO definition of health from 1948 ("Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.") is criticised for its very broad scope. However, in human medicine general agreement exists that health is much more than the absence of disease, and is achieved through a combination of physical, mental, emotional, and social wellbeing, which, together is commonly referred to as the *Health Triangle*. Translated to animals, this concept of health would mean that health encompasses animal welfare. We prefer to keep these apart for reasons of clarity, and stick for our conception of health to the minimal formulation of "absence of disease or infirmity", since the other aspects of wellbeing are already covered by animal welfare, and operationalised in terms of needs.

Next, we have to investigate what this means in terms of requirements for the cow. In order to do this, we will first have to discriminate diseases and infirmities by cause. An overview of the many causes for reduced health is shown in Figure 1. The infectious diseases are commonly divided into three groups: 1) highly pathogenic diseases (the OIE list); 2) other infectious diseases (commonly present at farms); and 3) diseases with a so-called multi-factorial cause. Non-infectious diseases are related to genetics, feed, physical damages and wounds.

<u>Non-infectious diseases</u> can be prevented by proper care-taking, good food, a physical environment that prevents injuries, and genetical breeding that takes health into account. This does not lead to substantial additional requirements as compared to the requirements based on the biological needs.

<u>Infectious diseases</u>, on the other hand, deserve more scrutiny. Does the prevention of disease also mean that pathogens should be ideally absent in the system in all cases? The current veterinary strategy is based on controlling contact structure (minimizing pathogen-host contact and contact rate), interference in the susceptibility of the pathogen (e.g. vaccination), and interfering in the infectivity of the pathogen. Animals can cope with a lot of pathogens themselves as long as they are present at a certain maximum level. So the total absence of pathogens is not only utopia, but not necessary at all.

Therefore, we take a different starting point in this BoR in dealing with infectious diseases in husbandry systems for dairy cows. Except for OIE-types of highly infectious diseases, we accept the presence of pathogenic agents in the cow or husbandry system, under the following conditions:

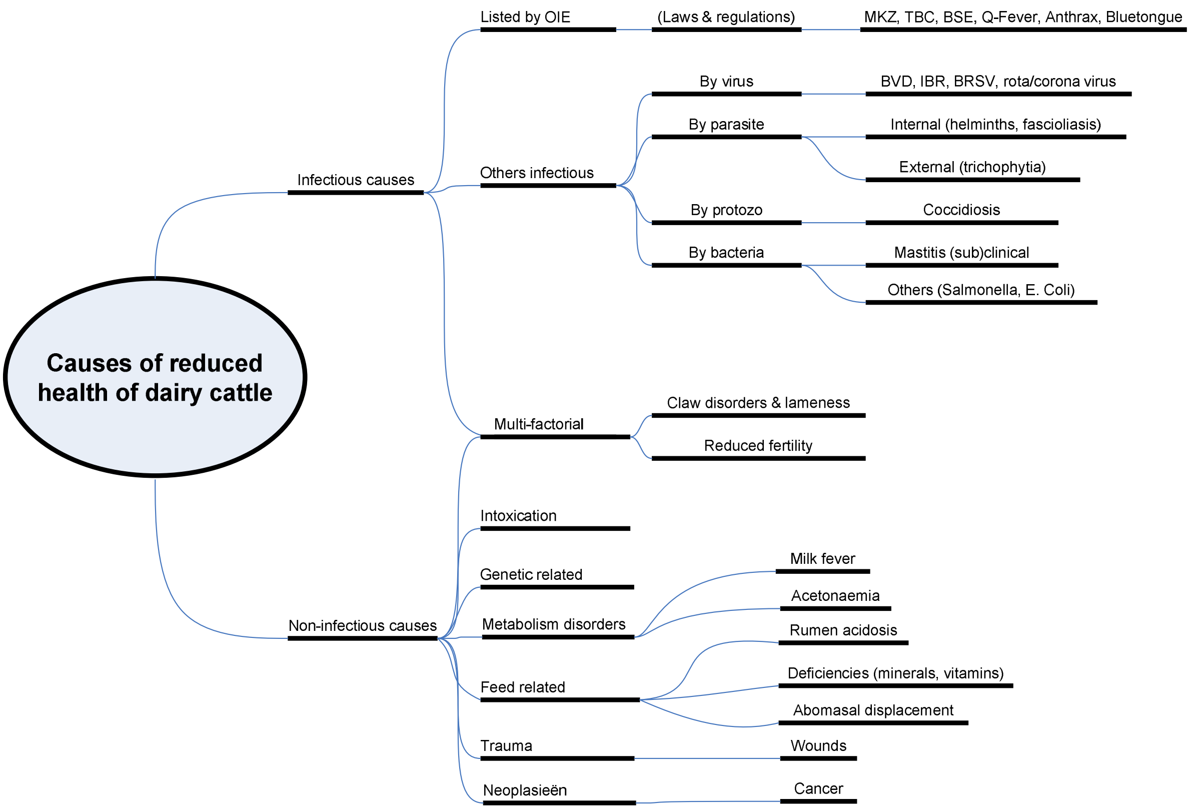
1. the dairy cow can cope with the levels of pathogens present;
2. does not suffer from chronic pain and stress (and principally will not die);
3. does not lead to an irreversible state with limitations to performance of biological needs and organ systems;
4. and keeps production levels stable in the long run.

Basically, this starting point implies that a cow can cope with the many and various causes that can reduce her health. So, in this BoR it is deemed acceptable that

- clinical symptoms of decreased health are visible,
- the cow can experience temporary and limited pain (but certainly not chronically), and
- production is temporarily disturbed (decreased milk production).

In this regard it is acceptable that the cow has contact with pathogens, that they enter the body and replicate. Moreover, despite all efforts we make, we also have to accept that some cows still can not cope with all situations and that losses of individual cows will occur.

Figure 1 Overview of causes of reduced health and some examples (after Rosenberger, 1994)



Mechanisms to cope with infectious diseases
To cope with the infectious causes of decreased health, the following ordered and combined strategy can be followed:

No.	Stadium or phase of pathogens	Mechanisms (animal / men)
1	Prevent the presence of the cause in the environment (e.g. contact)	Flee / protect – eradication
2	Prevent penetration or entry in the cow	Innate immune system / kill – limit in environment
3	Limit development (e.g. replication of pathogens in animal)	Innate and specific immune system / vaccinate
4	Limit negative effects and support coping of the animal	Coping / treatment, nurse and take care

A prominent role in these strategies is reserved for the immune system. The immune system of cows and mam-mals in general consists of an innate (general) immune subsystem (present at birth) and an adaptive or specific immune subsystem (developing in time after birth). The innate immune system consists of or is situated on:

- the skin, hair and horn structures
- Openings & orbicular muscles: anus, milk teats, vulva
- Reproduction organs: uterus
- The alimentary system: mouth (enzymes in saliva), throat (tonsils), intestine and stomach
- The respiratory system: nose, paranasal sinus, throat (tonsils), trachea, lung with mucosa
- Other mucosa of urinary passages, eyes, ears, and genital organs
- Cells and molecules present in blood, milk and other body fluids
- Lymph nodes

The adaptive immune system reacts in specific ways on exposure to agents and keeps a memory with regard to these agents. The effect of vaccination is based on this principle. As long as we do not keep cows in sterile circumstances, a certain level of contact with pathogens can be beneficial for health, and even taken as a requirement. In that case however, this ‘certain level’ should be quantified to be meaningful, and probably even specifically for each pathogen. Such knowledge is not available yet and not added to this BoR.

Category I - health requirements of the dairy cow
From the viewpoint of the cow and directly related to her mechanisms to cope with causes of decreased health, the following three general strategies can be listed:

A. Improve and develop the intrinsic characteristics of the cow and herd (genetic background, history)
B. Teach and develop the subsystems of the cow by positive stimulus (after birth and during life)
C. Enable the cow to let all subsystems function optimally

These general strategies involve at least the following requirements to the system. We have not been able to quantify these requirements yet.

- Fulfill all physiological and behavioural needs, as listed in paragraph 3.1;
- Provide colostrum after birth
- Allow for adequate levels of exposure to pathogens of the category of ‘other infectious diseases’ (the non-OIE-pathogens), in order to stimulate the adaptive immune system; This means for instance that calves should be reared at the same place as they will be when they are grown up;
- At the same time: limit the exposure to pathogens of the category of ‘other infectious diseases’ to levels that can be handled by the cow; This means at least that contact between cow and faeces should be reduced as much as possible;

Category II - health requirements not directly from the dairy cow
Besides requirements regarding health that are explicitly in the interest of the cow herself, a number of other requirements for dairy husbandry systems may be added because of other (mostly human) purposes. Since this BoR is explicitly restricted to requirements of the dairy cow, these external requirements are not added. Nonetheless, for reasons of completeness, we provide a list of important external requirements below.

A. Prevention of outbreaks of highly pathogenic OIE-diseases
    a. prevent introduction by any contact between pathogenic agents and the animal (prevent transfer through insects, vermin, new animals, people, equipment, etc.)
    b. prevent uncontrolled development of diseases within the husbandry system (keep clean, disinfect regularly, appropriate disposal of manure and dead carcasses, no faecal contamination of water and feed)
    c. Vaccination
    d. Stamping out
B. Food safety requirements and zoonoses transferred to people, the most important being:
    a. Somatic cell count (SCC) / mastitis
    b. Para-TBC
    c. Salmonella
    d. Q-fever
    e. BSE

Prevention of outbreaks of pathogenic diseases, other infectious diseases and food safety require actions in terms of monitoring and treatment, and requirements can be listed to define and enable these actions:

1. Monitoring (early recognition: identification of susceptible and potentially infected animals, surveillance and tracing of infected animals)
    i. Identification and Registration of individual animals (to enable tracking and tracing)
    ii. Registration at farm level
    iii. Regular inspection (visual), testing and disease detection (blood, milk, meat, manure)
2. Treatment (control measures)
    iv. Curative treatment of individual cows and herd
    v. Quarantine and/or movement restrictions
    vi. Report illness and diseases

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4 Brief of Requirements of the dairy cow

On the following pages the BoR of the dairy cow is presented. Requirements are organized according to several issues in the environment or the management, e.g. condition of resting places, condition of drinking water or daily schedule.

For each requirement we indicate to which needs it is related. Needs are coded with a two letter code (in the third column):

1. Fo = feed and foraging
2. Wa = water intake
3. RR = rest and rumination
4. So = social behaviour
5. Se = sexual behaviour
6. Ma = maternal behaviour
7. Lo = locomotion
8. Ex = exploration
9. Pl = play
10. Bo = body care and allogrooming
11. Th = thermoregulation
12. Re = respiration
13. He = health
14. Sa = safety

The references for each requirement are given in the fourth column with a number. These numbers refer to the reference list in paragraph 5.

The type of reference is given in the fifth column using the following codes: 1 = Based on peer-reviewed scientific publications; 2 = Based on handbooks or originating from practical, expert knowledge; and 3 = Based on both scientific and expert knowledge.

All areas

Amount / quantification	Comment	Need[a]	Ref. number	Ref. type
Spatial arrangement				
Possibility to move freely within the herd and within the area		Fo Wa RR So Se Ma Lo Ex Pl Bo He Sa	2, 5, 18, 54	3
Isolation facility within visual and hearing reach of herd members	Forced isolation only when necessary (e.g. calving or disease) Voluntary isolation must always be possible for the cow	So Ma Sa	35, 41, 60	3
Possibility to form subgroups within a herd	Sub groups usually consist of > 4 individuals	Fo Wa RR So Se Ma Lo Ex Pl Bo Sa	5, 37	1
Possibility to avoid contact with dung and urine on the floor		RR Lo He	5, 63, 74	3
Absence of cow trainers		Wa RR So Se Ma Lo Ex Pl Bo Sa	1, 79	1
Possibility to move ≥ 3 km/day	Cows should be able and challenged to do so	RR Lo He	63	2
Environment should be predictable and recognizable		Ex Sa	7, 35, 68, 76	3
Availability of shelter / protection against weather influences (sun, wind / draught, rain) of ≥ 3.5 m^2; ≥ 4.3 meters high; oriented north-south	This area corresponds with the space a cow needs to lie down and rise. Protection against the sun's UV rays when UV index > 5. Protection against draught when air speed < 0.2 m/s and ΔT between air flows < 5 ºC	RR So Lo Th He	24, 33, 60, 63	3
Grooming objects present	Rough, firm, solid, blunt object, placed horizontally or vertically	Bo He	5, 47, 77	3
Floor				
Frictional Coefficient = 0.4 - 0.5	Slipping will occur if slip resistance is too low and foot wear will occur if slip resistance is too high	RR So Se Lo Ex Pl Bo He Sa	33, 60, 64	3
No sudden changes in floor level or texture	The ability to perceive depth at ground level is poor. An uneven surface can stress the cows' feet	RR Ma Lo Ex Pl He Sa	35, 64	3
Dry		RR Ma Lo He	5, 11, 74	3
Peak sound				
Sound level < 80 dB	Louder noises will cause negative physiological effects	Ex Sa	69	1
Stray electricity				
< 0.35 Volt; < 1 mA[f]	Electricity causes negative physiological and behavioral effects. 0.35 V will be perceived by less than 10% of cows	Wa Sa	6, 50, 63	3
Climate				
Temperature Humidity Index < 71	THI[b] = db[c]-(0,55 - 0,55 * RH[d]) * (db-58)	Th Re He	21, 28, 32	3
Lower critical temperature = -2℃ (dry cow) / -14℃ (lactating cow, 27 kg FCM[e]/day); upper critical temperature = 25℃	The zone of thermo neutrality shifts downwards as milk production, feed intake and heat production increase	Th He	2, 22, 25, 71	3

[a]: Fo = feed and foraging; Wa = water intake; RR = rest and rumination; So = social behaviour; Se = sexual behaviour; Ma = maternal behaviour; Lo = locomotion; Ex = exploration; Pl = play; Bo = body care and allogrooming; Th = thermoregulation; Re = respiration; He = health; Sa = safety. [b]: THI = Temperature Humidity Index. [c]: db = Dry bulb temperature (℉). [d]: RH = relative humidity/100. [e]: FCM = Corrected milk for fat (4%). [f]: mA = milliamperes

Feeding place(s)

Amount / quantification	Comment	Need[a]	Ref. number	Ref. type
Spatial arrangement of feeding places				
Width ≥ 1 meter	More space should be provided if mangers are not demarcated	Fo So	29	1
Positioned at ground level	Eat in natural grazing position (with head downward)	Fo	3, 63	3
Availability of feeding places				
> 1/cow	Cows like to eat simultaneously	Fo So	3, 9, 63, 73, 76	3
Surface of feeding places				
Smooth		Fo	56	2
Availability of feed				
24 hours/day		Fo	56, 63	2

[a]: Fo = feed and foraging; Wa = water intake; RR = rest and rumination; So = social behaviour; Se = sexual behaviour; Ma = maternal behaviour; Lo = locomotion; Ex = exploration; Pl = play; Bo = body care and allogrooming; Th = thermoregulation; Re = respiration; He = health; Sa = safety

Resting area(s)

Amount / quantification	Comment	Need[a]	Ref. number	Ref. type
Floor of resting area				
Comfortable: shock absorbing and compressible (soft)	To cushion the shock to the cows body as she lies down and to support her body	RR	11, 18, 22, 63, 68	3
Spatial arrangement of resting area				
> 1 resting spot /cow	Longitudinal space ≥ 300% of back length (shoulders to hips); lateral space ≥ 200% of hip width; forward lunge space ≥ 78 % of back length and no obstacles on the floor. No obstacles during the act of rising and lying and during lying down. Cows should be able to choose a resting spot that gives undisturbed rest, where they are not trodden on or kicked by other cows	RR So He	4, 5, 17, 20, 60	3
Free choice of resting spot	Cows have preferences for certain resting spots (depending on e.g. the proximity of herd members, drinking or eating places and whether it is indoors or outdoors)	RR So	28, 46, 60, 74	3
Possibility to keep ≥ 2 meter interanimal distance	When lying down cows keep within 2 - 3 meter from one another	RR So	33	2
Resting area ≥ 360 m^2/cow	Cows do not increase distance larger than 12 meter between them when given more space	RR So	48, 55	1
Availability of resting places				
≥ 24 hours/day		RR So	ev	2

[a]: Fo = feed and foraging; Wa = water intake; RR = rest and rumination; So = social behaviour; Se = sexual behaviour; Ma = maternal behaviour; Lo = locomotion; Ex = exploration; Pl = play; Bo = body care and allogrooming; Th = thermoregulation; Re = respiration; He = health; Sa = safety

Cow traffic

Amount / quantification	Comment	Need[a]	Ref. number	Ref. type
Traffic alleys				
.6*W[b] (one way); 3.8*W (two way); L[c]+2.7*W (food and water on one side); 2*L+1.5*W (food and water on both sides)	1Wide enough to provide easy cow traffic	Lo	22	2
Passage points				
1,5*W+0.1	Wide enough for cows to pass simultaneously	Lo	22	2

[a]: Fo = feed and foraging; Wa = water intake; RR = rest and rumination; So = social behaviour; Se = sexual behaviour; Ma = maternal behaviour; Lo = locomotion; Ex = exploration; Pl = play; Bo = body care and allogrooming; Th = thermoregulation; Re = respiration; He = health; Sa = safety. [b]: W = Average shoulder width of 20% biggest cows. [c]: L = Average pin bone to point of shoulder length of 20% biggest cows

Drinking facility

Amount / quantification	Comment	Need[a]	Ref. number	Ref. type
Spatial arrangement of drinking facility				
≥ 0.06 m^2/cow; length ≥ 50 mm/cow; depth ≥ 60 mm; water surface at 0.61*H[b] from floor and ≥ 50 mm below brim of drinking facility	Easy access for all cows	Wa So Th He	22, 56	2
Management of drinking facility				
Daily cleaning		Wa So Th He	22	2
Availability of drinking water				
Ad libitum; 24 hours/day		Wa So Th He	2, 22, 53, 56	3
Flow rate > 20 Liter/minute	Cows can drink with speeds up to 20 Liter/minute	Wa	22	
Availability of drinking facilities				
0,15*n[c] and ≥ 2/herd	Dimensions should be based on the total herd	Wa So	22	2
Within 250 meter distance of the cows' locations, but not in the resting area	Cows want to drink after being milked and after feeding. Resting areas should not become wet	Wa	22, 58, 60	3

[a]: Fo = feed and foraging; Wa = water intake; RR = rest and rumination; So = social behaviour; Se = sexual behaviour; Ma = maternal behaviour; Lo = locomotion; Ex = exploration; Pl = play; Bo = body care and allogrooming; Th = thermoregulation; Re = respiration; He = health; Sa = safety. [b]: H = shoulder height. [c]: n = number of cows in the herd

Maternity unit

Amount / quantification	Comment	Need[a]	Ref. number	Ref. type
Spatial arrangement of maternity unit				
Separated from the herd, voluntary entering and exiting by the cow possible	Cows look for a hidden place to give birth, they leave the calf there for some time before introducing it into the herd. During that time the cow herself leaves and enters the lair numerous times	So Ma	2, 10, 33, 60	3
Possibility to supervise without disturbance of the cow	Supervision enables timely assistance when necessary (at least after 1 hour (cows) or 2 hours (heifers) from the start of labor)	Ma	10, 73	3
Sides ≥ 1,8*L[b]		Ma	22	2
Floor of maternity unit				
Clean, dry and soft bedding	Without e.g. manure spots	Ma He	2, 77	2
Availability of maternity unit				
1/calving cow; before, during and after calving	Available 3 - 7 days before calving, during calving and after calving until calf is introduced into the herd. The hider phase can last up to 20 days after calving	So Ma	49	2

[a]: Fo = feed and foraging; Wa = water intake; RR = rest and rumination; So = social behaviour; Se = sexual behaviour; Ma = maternal behaviour; Lo = locomotion; Ex = exploration; Pl = play; Bo = body care and allogrooming; Th = thermoregulation; Re = respiration; He = health; Sa = safety. [b]: L = Average pin bone to point of shoulder length of 20% biggest cows

Human-cow interaction

Amount / quantification	Comment	Need[a]	Ref. number	Ref. type
Handling by humans				
Gentle	Negative: hitting, slapping, shouting and fast movement. Positive: petting, stroking, hand resting on the animal, talking and slow deliberate movement	Sa	10, 19, 39	1
No driving, cows should be able to move at their own pace	To avoid stress	Sa	2, 10, 14	3
Dehorning				
None		So Bo He	5	1
Tail docking				
None	The tail is a signaling device, has functions in locomotion and removes flies	So Bo He	5, 63	3

[a]: Fo = feed and foraging; Wa = water intake; RR = rest and rumination; So = social behaviour; Se = sexual behaviour; Ma = maternal behaviour; Lo = locomotion; Ex = exploration; Pl = play; Bo = body care and allogrooming; Th = thermoregulation; Re = respiration; He = health; Sa = safety

Herd

Amount / quantification	Comment	Need[a]	Ref. number	Ref. type
Size				
> 4 cows	Herd size has a minimum because of predation fear and a maximum because of hierarchy in the group and the ability for a cow to remember her place in hierarchy. There are no clear indications on the optimal and maximal herd size, however the optimum could be set at 50 individuals, based on the suggestion that cows can recognize and remember about 50-70 other cows as individuals	So Se Ex Pl Bo Sa	66, 74	3
Composition				
≥ 1 familiar herd member present	For safety and allogrooming	So Se Ex Pl Bo Sa	8, 34, 76	2
Mixing only in subgroups of familiar herd member and only when necessary	Mixing of individual animals is stressful. Problems related to social integration are higher for the introduced animals than the resident animals. When mixing is necessary this should be done with intervals of at least 45 days	So Sa	2, 15, 63	3

[a]: Fo = feed and foraging; Wa = water intake; RR = rest and rumination; So = social behaviour; Se = sexual behaviour; Ma = maternal behaviour; Lo = locomotion; Ex = exploration; Pl = play; Bo = body care and allogrooming; Th = thermoregulation; Re = respiration; He = health; Sa = safety

Feed

Amount / quantification	Comment	Need[a]	Ref. number	Ref. type
Energy				
FUL = $(42.4 \cdot LW^{0.75\ c} + 442 \cdot FCM^{d}) \cdot (1+(FCM-15) \cdot 0.00165)$		Fo He	26	2
Dry matter in diet				
$TDMI^{e} = FIC^{f}/SV^{g}$		Fo He	26	2
Roughage				
$SV_{need} \geq 1$	$SV_{need} = 1{,}0+(M^{h}-25) \cdot 0{,}008-(\%F^{i}-4{,}4\%) \cdot 0{,}050$	Fo He	26	2
Ad libitum		Fo He	77	2
Protein				
$IDP^{j}_{maintenance}$: $(2.75 \cdot BW^{0.5}+0.2 \cdot BW^{0.6})/0.67$ $IDP_{milk\ production}$: $1.396 \cdot E+0.000195 \cdot E^{2}$		Fo He	26	2
$RDP^{k} > 0$		Fo He	26	2
Trace elements				
Cobalt = 2.4 mg/d; Copper = 260 mg/d; Manganese = 940 mg/d; Selenium = 4.22 mg/d; Zinc = 763 mg/d; Calcium = 100 g/d; Phosporus = 79 g/d; Magnesium = 56 g/d; Sodium = 33 g/d; K = 190 g/d; Chlorine = 66 g/d; Sulfur = 2 g/kg dry matter; Iodine = 12 mg/d; Iron = 300 mg/d	For adult cow producing 40 kg milk per day	Fo He	83	2
Colostrum				
Ad libitum within 3 hours of birth	For the intake of immunoglobulin from the mother	Fo He	33	2
Palatability				
Not molded or fermented, no toxic substances, not older than 24 hours, no saliva of other animals and no dung/slurry present	Cows have preferences based e.g. on energy return, possible contamination/toxicity, freshness, taste and convenience	Fo He	2, 3, 33, 63	3
Composition				
Variation	Cows want to select food herself from a varied diet	Fo He	63	
Possibility to manipulate the food	To ensure choice and variation	Fo He	52, 63	
Length of grass in pasture				
> 3 cm		Fo He	34	2

[a]: Fo = feed and foraging; Wa = water intake; RR = rest and rumination; So = social behaviour; Se = sexual behaviour; Ma = maternal behaviour; Lo = locomotion; Ex = exploration; Pl = play; Bo = body care and allogrooming; Th = thermoregulation; Re = respiration; He = health; Sa = safety. [b]: FUL = Feed Unit of Lactation. [c]: LW = Live Weight. [d]: FCM = Corrected milk for fat (4%). [e]: TDMI = Total Dry Matter Intake (kg dry matter/day). [f]: FIC = Feed Intake Capacity (SV/day) g. FIC = $((8.743+3.563 \cdot (1-e^{-1.140 \cdot a})) \cdot e^{0.3156 \cdot (1-e[-0.05889 \cdot ld])} \cdot 1-0.05529 \cdot (g/220))$. SV = Structure Value (SV units/kb dry matter). SV = (dry matter ratio $forage_1$ in diet * SV $forage_1$) + (dry matter ratio $forage_2$ in diet * SV $forage_2$)+ (dry matter ratio $concentrate_1$ in diet * SV $concentrate_1$) + (dry matter ratio $concentrate_2$ in diet * SV $concentrate_2$) + (dry matter ratio $forage_n$ in diet * SV $forage_n$) + (dry matter ratio $concentrate_n$ in diet * SV $concentrate_n$). [h]: M = milk production (kg/day). [i]: %F = fat percentage. [j]: IDP = Intestinal Digestible Protein (grams/day). [k]: RDP = Rumen Degradable Protein

Drinking water

Amount / quantification	Comment	Need[a]	Ref. number	Ref. type
Temperature				
15 -28 ℃		Wa He	2, 56	2
pH				
6.5 - 8.5		Wa He	56	2
Composition				
Nitrate < 44 mg/L		Wa He	56	2
Nitrate nitrogen < 10 mg/L		Wa He	56	2
Total Soluble Salts < 1000 mg/L		Wa He	56	2
Sulfate^{-} < 1000 mg/L for adult cows and < 500 mg/L for calves; Aluminum < 0.5 mg/L; Arsenic < 0.05 mg/L; Boron < 5.0 mg/L; Cadmium < 0.005 mg/L; Chromium < 0.1 mg/L; Cobalt < 1.0 mg/L; Copper < 1.0 g/L; Fluorine < 2.0 mg/L; Lead < 0.015 mg/L; Manganese < 0.05 mg/L; Mercury < 0.01 mg/L; Nickel < 0.25 mg/L; Selenium < 0.05 mg/L; Vanadium < 0.1 mg/L; Zinc < 5.0 mg/L	Toxin concentration below generally considered safe concentrations	Wa He	56	2
No contamination of drinking water by manure or feed		Wa He	78	1

[a]: Fo = feed and foraging; Wa = water intake; RR = rest and rumination; So = social behaviour; Se = sexual behaviour; Ma = maternal behaviour; Lo = locomotion; Ex = exploration; Pl = play; Bo = body care and allogrooming; Th = thermoregulation; Re = respiration; He = health; Sa = safety.

Air

Amount / quantification	Comment	Need[a]	Ref. number	Ref. type
Composition				
Dust particles < 5 mg/m^3 (particle size ≤ 5 μm); or < 10 mg/m^3 (particle size > 5 μm)	TLV[b] value for humans	Re He	22, 82	2
Carbon dioxide < 3000 ppm[c]; Methane < 1000 ppm; Hydrogen Cyanide < 4.7 ppm; Hydrogen Sulfide < 5 ppm; Ammonia < 30 ppm	TVL value for humans	Re He	23	1
Oxygen~18%	Similar to outdoor air	Re He	ev	2

[a]: Fo = feed and foraging; Wa = water intake; RR = rest and rumination; So = social behaviour; Se = sexual behaviour; Ma = maternal behaviour; Lo = locomotion; Ex = exploration; Pl = play; Bo = body care and allogrooming; Th = thermoregulation; Re = respiration; He = health; Sa = safety. [b]: TLV = Threshold Limit Value. [c]: parts per million

Cow-calf contact

Amount / quantification	Comment	Need[a]	Ref. number	Ref. type
Availability				
Daily physical contact between cow and calf until natural weaning	Natural weaning occurs normally 6-12 months after calving and coincides with a feed intake of > 1 kg dry matter per day	Ma	45, 75	3
Milking frequency by calf suckling				
8 - 10/day, ≥ 90 minutes in total	At onset of lactation with decrease in time until natural weaning at 8-12 months	Ma	5, 45	1

[a]: Fo = feed and foraging; Wa = water intake; RR = rest and rumination; So = social behaviour; Se = sexual behaviour; Ma = maternal behaviour; Lo = locomotion; Ex = exploration; Pl = play; Bo = body care and allogrooming; Th = thermoregulation; Re = respiration; He = health; Sa = safety

Machine milking

Amount / quantification	Comment	Need[a]	Ref. number	Ref. type
Milking frequency				
2 - 3 times/day (regular intervals 8 - 17 hours)	~ 1 for 10 liters of daily production, in case of voluntary automatic milking cows get milked with an average interval of 9.2 hours	He	40, 43, 57, 60, 77	3
Process				
36 - 40 kPa[b] vacuum	Vacuum in milking claw during maximum milking speed	He	38	2
Latency period ~ 50 seconds	Period between activation (e.g. by cleaning of the udder) and milking	He	33	2
Pulsation cycle with b-phase ≥ 30%, d-phase ≥ 15% and c-phase ≥ 10%	b-phase = vacuum phase or milking phase, d-phase = the liner closed phase, c-phase = transition phase	He	16, 38, 62	2
Diameter of liner fits to average diameter of teats		He	38	
No blind milking	Blind milking occurs when milking speed < 0.3 kg/minute for a period of > 6 seconds	He	16, 54, 51	3
Cleaning of udder and teats before and after milking		He	13, 16	2
Cleaning by dipping using teat dip with disinfectants		He	81	2
No waiting times	Traditional waiting areas are stressful. Waiting time only allowed if the waiting area is (similar to) the resting area	He	ev	2

[a]: Fo = feed and foraging; Wa = water intake; RR = rest and rumination; So = social behaviour; Se = sexual behaviour; Ma = maternal behaviour; Lo = locomotion; Ex = exploration; Pl = play; Bo = body care and allogrooming; Th = thermoregulation; Re = respiration; He = health; Sa = safety. [b]: kPa = kilopascals

Daily schedule

Amount / quantification	Comment	Need[a]	Ref. number	Ref. type
Time available for foraging/eating				
In case of grazing: ≥ 8 hours/day, spread over several periods Otherwise: sufficient time for feed intake	Cattle graze 8 - 12 hours/day	Fo He	5, 18, 30, 33, 63	3
Time available for resting				
≥ 8 hours/day	Cows normally lie down 8 - 14 hours/day. Resting includes the activity of lying down, rumination and sleeping)	RR He	5, 14, 18	1
Time available for rumination				
≥ 4 hours/day, spread over several periods	Rumination takes 4 - 8 hours/day in periods of 10 - 60 minutes. Cows prefer to lie down during rumination	Fo RR HE	5, 18, 33	3
Time available for sleeping				
≥ 30 min/day, spread over several periods	Cattle have REM sleep for 30 - 45 min/day, during 6 - 10 periods. Cows lie down when sleeping	RR He	5, 41	3

[a]: Fo = feed and foraging; Wa = water intake; RR = rest and rumination; So = social behaviour; Se = sexual behaviour; Ma = maternal behaviour; Lo = locomotion; Ex = exploration; Pl = play; Bo = body care and allogrooming; Th = thermoregulation; Re = respiration; He = health; Sa = safety

Light intensity and cycle

Amount / quantification	Comment	Need[a]	Ref. number	Ref. type
Diurnal cycle				
14 - 16 hours of day (> 200 lux) and 10 - 8 hours of night (< 50 Lux) , with light intensity changes similar to a normal day with gradual sunset and sunrise		Fo Wa RR So Se Ma Lo Ex Pl Sa	2, 12, 25, 27, 33, 44, 61, 63, 66	3

[a]: Fo = feed and foraging; Wa = water intake; RR = rest and rumination; So = social behaviour; Se = sexual behaviour; Ma = maternal behaviour; Lo = locomotion; Ex = exploration; Pl = play; Bo = body care and allogrooming; Th = thermoregulation; Re = respiration; He = health; Sa = safety

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