Understanding natural behavior to improve dairy goat (*Capra hircus*) management systems

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ABSTRACT: Public interest is stimulating farming industries to improve animal welfare in production systems. Indoor housing of ruminants has received scrutiny because of perceived intensiveness and lack of naturalness. Animal welfare has traditionally focused on health benefits (e.g., bedding management and reducing disease) and reducing negative experiences (e.g., painful husbandry practices). Recent attention to animals having "a life worth living" extends expectations to provide increased care and opportunities for positive experiences and natural behaviors. Although not all natural behaviors necessarily contribute to improved welfare, we present evidence for why many are important, and for how they can be promoted in commercial systems. Worldwide, commercial dairy goats (*Capra hircus*) are frequently housed in large open barns with space to move and soft bedding for lying; however, this is not sufficient to promote the range of natural behaviors of goats, which in turn suggests that commercial housing could be improved. The basis for this thinking is from the range of behaviors expressed by the *Capra* genus. Collectively, these species have evolved cognitive and behavioral strategies to cope with harsh and changing environments, as well as variable and limited vegetation. The rocky and often steep terrain that goats inhabit allows for predator avoidance and access to shelter, so it is not surprising that domesticated goats also seek out elevation and hiding spaces; indeed, their hoof structure is designed for the movement and grip in such rugged environments. The browsing techniques and flexibility in diet selection of wild, feral and extensively managed goats, appears to be equally important to housed goats, highlighting the need for more complexity in how and what goats are fed. Goats naturally live in small, dynamic groups, governed by complex social structures in which horns play a strong role. Commercial housing systems should consider the benefits of more natural-sized social groups and revisit the rationale behind horn removal. We suggest that cognitive stimulation is a potential welfare improvement for goats in commercial settings. Goat cognitive abilities, which enabled success in complex and variable social and physical environments, are unchallenged in uniform environments, potentially leading to negative affective states. We make suggestions for housing improvements that could be readily adopted into current systems without compromising production efficiency.

Key words: behavior ecology, browsing, climbing, housing, welfare

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INTRODUCTION

There are around 200 million dairy goats worldwide. The majority of these goats are in Africa (40%)

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and Asia (52%) (FAO, 2016), but the highest production per animal values are in Europe and North America. Although the FAO (2016) reports that on average European goats produce 290 kg/goat and that this is between 3 and 6 times as much as goats in the Americas, Asia, and Africa, evidence from individual farms demonstrate that these averages grossly underestimate actual annual production on some farms in these regions (e.g., United Kingdom 24 farm averages: 300 to 1,600 kg/goat, Anzuino et al., 2010; United States, individual records for 2,194 does: 268 to 2,394 kg/goat, American Dairy Goat Association, 2018). A primary reason for the higher production is the use of intensive housing systems and factors that are associated with these systems (e.g., feeding regimes, climate control, and reduced parasites). The potential to increase productivity in dairy goats highlights two points as follows: 1) high producing regions will continue to strive for improvement and expansion, putting more pressure on the systems and the goats within them, and 2) there is pressure to increase production in the regions of the world currently not using intensive housing systems, which potentially will result in millions of more goats being housed indoors (e.g., Knights and Garcia, 1997). Increased goat production has also been heralded as a way to cope with climate change (Darcan and Silanikove, 2018), suggesting that the increase in dairy goat numbers and intensification of management will continue.

There is growing consumer concern for the welfare of production animals (Broom, 2010). This interest has created a need to provide assurance that animals have “a life worth living” (FAWC, 2009; Yeates, 2011) or more simply, “a good life” (FAWC, 2009; Yeates, 2017). The concept of animal welfare is based on human perspectives as it is a social construct (Fraser, 2008). Animal welfare encompasses an animal’s physical state (e.g., health and production), affective state (e.g., its experiences), and ability to perform natural behavior (Fraser et al., 1997); however, there is different emphasis placed on these three components by stakeholders. For example, there is more dairy goat research on health (e.g., Reina et al., 2009), production (e.g., Goetsch et al., 2011; Clark and Garcia, 2017), and reducing painful experiences (e.g., Hempstead et al., 2018) than on natural behavior. The expression of natural behaviors, defined as those that can be observed in animals that are not under the influence of humans (Yeates, 2018), can reveal how well we are meeting this aspect of welfare in our production systems. A good way to address public concern about intensification is to design systems that promote naturalness (e.g., movement and social contact; Weary and von Keyserlingk, 2017) and allow animals to meet their behavioral needs (i.e., internally motivated behaviors that, if prevented, compromise the animal’s welfare; Friend, 1989). This review describes dairy goat housing systems, discusses the natural behaviors of goats based on evidence from wild or feral *Capra* spp. where possible, and considers how to promote these behaviors in indoor dairy goat housing systems.

COMMERCIAL DAIRY GOAT HOUSING

The available information on commercial dairy goat housing and management practices is limited, with many recommendations based on practice rather than on science-based research. The majority of published systematic research or producer-reported surveys are out of Europe or New Zealand, with extremely limited information from North America. In general, dairy goat facilities are variable across regions, climates, availability of local materials, breeds, and herd sizes; however, large commercial systems that rely on high per animal milk yields are more consistent in their approach to housing (Rubino et al., 2011). Intensive outdoor systems may be found in temperate regions of Europe (Italy, Sandrucci et al., 2018) and New Zealand (Prosser and Stafford, 2017). Although some farms provide a combination of indoor and outdoor access (e.g., United Kingdom, Anzunio et al., 2010; Norway, Muri et al., 2013; Italy, Sandrucci et al., 2018), intensive systems around the world more commonly house goats fully indoors (Italy and Portugal, Battini et al., 2015; New Zealand, Prosser and Stafford, 2017; Norwegian producer-reported survey, Simensen et al., 2010). Herd sizes reported in Europe range from dozens to hundreds: 16 to 154 goats and 50 to 236 goats in Norway (Simensen et al., 2010; Muri et al., 2013, respectively), 80 to 910 goats in United Kingdom (Anzuino et al., 2010), and 18 to 912 goats in Italy (Battini et al., 2016). In North America and New Zealand, herd sizes can reach into the thousands, with a herd of 3,000 goats in New Zealand (Te Arawa Primary Sector Inc., 2018) and a farm in Wisconsin, United States reporting a 2019 milking herd of 10,000 goats (Drumlin Dairy, 2018). Herds are normally subdivided into groups dependent on the facility and total herd size, with large ranges in group size: 11 to 173 in Norway (Muri et al., 2013), 61 to 124 in United Kingdom (Anzuino et al., 2010), and 7 to 192 in Italy (Battini et al., 2016).

Indoor facilities are typically single-level units (e.g., Aztech Buildings, 2018), with a range of space allowances (e.g., New Zealand, 2.0 to 3.0 m^2/goat, MPI, 2018; Norway, 0.6 to 2.1 m^2/goat, Muri et al., 2013; Canadian producer-reported survey, 1.0 to 2.8 m^2/goat, Oudshoorn et al., 2016). Anecdotal reports suggest that some farms provide vertical space allowance (e.g., climbing structures); however, this has not been systematically surveyed. Bedding substrates vary between regions, but straw (United Kingdom, Anzuino et al., 2010; Italy, Battini et al., 2016) and wood shavings (Norwegian producer-reported survey, Simensen et al., 2010) are common. Most housing systems provide feed at ground level along the outside of a feed rail that is accessible by machinery along a drive alley, but depending on the feed, elevated racks, troughs, and conveyor belts are also used (e.g., Upreti et al., 2005). The design of the feed rail can vary widely as it is dependent on whether the goats are horned (Loretz et al., 2004; Nordmann et al., 2015). Space allowance at the feed rail also varies (e.g., minimum recommendation of 40 cm/goat in New Zealand, MPI, 2018; 18 to 42 cm/goat in Norway, Muri et al., 2013; 17 to 95 cm/goat in Italy, Battini et al., 2016). A concrete skirt behind the feed rail (e.g., Ireland, DAFM, 2010) may aid manure removal from this heavily used area.

Commercial dairy goat systems are thought to provide health and productions benefits, including consistent access and quality of feed (Morand-Fehr et al., 2007), shelter from the elements and predation (Sevi et al., 2009), and reduced parasitism (Torres-Acosta and Hoste, 2008). These beneficial factors, combined with genetic improvements, have generally improved milk production (Goetsch et al., 2011). However, the design goals of these systems have been to automate feeding, cleaning, and milking, with less focus on the needs of individual goats; thus, there is an opportunity to improve quality of life and overall welfare of the goats in these systems. There is evidence that consumers feel negatively toward intensive indoor housing (e.g., NAWAC, 2011). Shifting housing design to include a focus on the individual animal will allow for commercially housed goats to achieve a wider behavioral repertoire closer to that of goats in natural systems. As noted by Shackleton and Shank (1984), there is much to be learned from observing the behavior of goats under natural conditions to help in the design of appropriate domestic housing systems. The remainder of this review will explore the literature describing the natural behavior of wild, feral and extensively managed goats, and how this information can be applied to indoor dairy goat production systems.

NATURAL BEHAVIOR OF GOATS

Physical Environment

Domestication of goats occurred approximately 10,000 yr ago in the Middle East (Zeder and Hesse, 2000); the success of goats at coexisting with humans can be attributed to their ability to sustain themselves in harsh topography, meaning they were useful sources of milk, fibre and meat to humans, particularly when resources were limited. Studies of a number of the *Capra* genus species confirm their ability to thrive in steep, mountainous terrain. Presence at high elevation is common (e.g., 2,200 to 2,800 m, Alpine ibex [*Capra ibex ibex*]; Parrini et al., 2003) but is often seasonal, with Bezoar ibex (*Capra aegagrus aegagrus*; Gavashelishvili, 2009), wild goats (*C. aegagrus*; Sarhangzadeh et al., 2013), and the Asiatic ibex (*Capra ibex sibirica*; Fox et al., 1992) moving to lower elevations in the winter months. Dry, forested, and nonsnowy terrain near steep rock faces is frequented by Bezoar ibex (*C. aegagrus aegagrus*; Diker et al., 2009), Markhor (*Capra falconeri*; Schaller and Amunallah Khan, 1975), and East Caucasian tur (*Capra cylindricornis*; Weinberg et al., 2010). Similarly, feral goats (*Capra hircus*) in various parts of the world demonstrate their preference for rocky terrain (New Zealand, Parkes, 1984; United States, Kessler, 2002; Scotland, Shi et al., 2005; Iran, Sarhangzadeh et al., 2013). Regardless of the species, a commonality is that goats are comfortable on elevated rock faces and steep cliffs, also using them as potential sources of minerals (Bhatnagar, 1997), vantage points to survey their environment (Iribarren and Kotler, 2012) and to escape predation (Parkes, 1984; Diker et al., 2009; Sarhangzadeh et al., 2013).

Although the affinity of goats for climbing and high elevations is unsurprising, their use of caves and other hiding spaces may not be as intuitive. There are a number of reports of feral goats using caves for nighttime resting (Boyd, 1981; Shi et al., 2003; Shi et al., 2005), during rainfall events (Boyd, 1981), and as means of avoidance when being pursued during culling efforts (Kessler, 2002). Extensively managed milking goats in a European alpine environment were also found to use caves, with particularly high usage reported in the afternoons when temperatures were more than 22 °C (Zobel et al., 2018). Therefore, the opportunity to hide serves a variety of purposes to goats, by providing shelter during adverse conditions and as security. Providing additional shelter within an indoor facility may seem unnecessary because climate and predation are controlled, but it may provide for one need that is not typically considered in large commercial settings—the opportunity for individuals to isolate from others (Zobel et al., 2017). Rocky terrain, steep cliff faces, and caves provide complexity and choice to the individual. Although the importance of providing natural environments that are both complex and cognitively enriching is often recognized in zoos (e.g., Clark, 2017; Hopper, 2017) such spaces are generally not provided in commercial housing systems.

The preference of goats for drier, rocky areas appears to have a hoof health benefit. The *Capra* genus has evolved flexible, cloven hooves to facilitate movement on rough, steep rocky terrain (Straus, 1987); however, this has resulted in the hooves growing continuously to counteract constant wear. This hoof anatomy also results in a unique ability (for ruminants) to climb trees, and goats will take advantage of this to reach leaves (El Aich et al., 2007). Indeed, goats' hooves have the ability to withstand a variety of challenging conditions, including traveling significant distances. For instance, the Alpine ibex (*C. ibex ibex*) can have home ranges of more than 400 ha (Parrini et al., 2003), and even extensively managed domestic goats (*C. hircus*) can walk several kilometers per day when foraging (e.g., 3.5 to 5.5 km/d, Texas, United States, Askins and Turner, 1972; 3.3 to 3.9 km/d, West Africa, Ouédraogo-Koné et al., 2006). In an alpine environment, milking does (*C. hircus*) that traveled upward of 3 km in a 24-h period had convex, solid yet spongy hoof soles and toes that were similar in length to a recently trimmed hoof, despite the hooves not being trimmed for at least 5 mo (H. Freeman, personal communication). In contrast, when goats are kept in environments devoid of climbing opportunities or hard surfaces, hoof overgrowth is a constant management issue. For instance, over a 2-yr period, on a Qatarian wildlife preserve, 20% goat deaths (*C. aegagrus*) and 8% deaths of Nubian ibex (*Capra nubiana*) were euthanasia due to hoof overgrowth (Deiss et al., 2010). Indeed, hoof overgrowth has been observed even in feral goats (*C. hircus*) on an island environment lacking in rocks (Geist, 1960).

The natural environment for goats is often harsh, yet their ability to thrive in areas of high elevation, and steep, mountainous terrain where many other species cannot, demonstrates their flexibility and adaptability. Although it is not sensible to provide harsh environments in a production context, the key point is that goats have adapted unique abilities to cope with these complex and variable environments. Elevated areas, hard dry surfaces, and hiding spaces are environmental features that are part of the natural behavioral repertoire of wild and feral goats, and this must be allowed for within a commercial setting when the aim is to improve welfare.

Feeding Environment

Goats are classified as both browsers and grazers (Goetsch et al., 2010). They are highly efficient at digesting poor quality roughage (Silanikove, 1997) and adjust to a variety of vegetation types depending on conditions and location. Their diet flexibility in changing conditions (Ngwa et al., 2000; Dziba et al., 2003; Egea et al., 2014), and even in artificially imposed vegetation limitations (Chynoweth et al., 2013) makes the label "mixed-feeding opportunists" fitting (Lu, 1988). Flexible lips and tongues allow goats to be selective for buds, leaves, fruits, and flowers that contain more protein and are more digestible than stems (Ngwa et al., 2000; Ouédraogo-Koné et al., 2006). This ability to pick and choose forages results in relatively higher nutritional intake quality than would be predicted from analysis of the whole-plant diet (Lu, 1988). Goats also possess an ability to "probe" and "shake" parts of individual plants, which can help them avoid noxious insects on individual leaves (Berman et al., 2017). An ability to differentiate between and tolerate bitter flavors (Bell, 1959) likely contributes to this diet flexibility. Furthermore, their tolerance of potentially toxic compounds (e.g., hydrolyzable tannins; Malechek and Leinweber, 1972; Jansen et al., 2007) further expands their dietary repertoire and may have anthelmintic benefits (Kahiya et al., 2003).

Goats demonstrate highly flexible foraging behavior in changing conditions. For example, when given a choice of nine shrubs and trees and five grass types, extensively managed Argentinian Creole goats (*Capra aegagrus hircus*) included grasses when they were available in the summer (13% of their diet was just one type of grass), but in the winter when grasses dwindled, the goats shifted their intake to 98% shrubs and trees (Egea et al., 2014). All members of the *Capra* genus have demonstrated the ability to adjust remarkably well to the habitat they are in, and this is especially noticeable in the success of introduced, feral goats in island environments. Their ability to shift to different vegetation has been the detriment of many island ecosystems (e.g., Campbell and Donlan, 2005; Chynoweth et al., 2013), with feral goats permanently disrupting native tree populations with their debarking capabilities (Spatz and Mueller-Dombois, 1973). Goats also show flexibility in feeding behavior time budgets. Feeding duration is impacted by time of day (e.g., feral goats [*C. hircus*]; Shi et al., 2003), temperature (e.g., Alpine ibex [*Capra ibex*]; Aublet et al., 2009), season (e.g., Nubian ibex [*Capra nubiana*]; Tadesse and Kotler, 2010; Tadesse and Kotler, 2011; Tadesse and Kotler 2011) and aspects of the social group affecting access to feed such as competition and social facilitation (e.g., extensively managed milking goats [*C. hircus*]; Shrader et al., 2007; Zobel et al., 2018).

Dietary flexibility is exhibited by not only what goats are eating but also how they are eating, and this has been shown in a number of studies focusing on extensively managed goats (*C. hircus*). Lu (1988) considered goats to be "eye-level" feeders and suggested the potential benefits of this to avoid predators and reduce risk of exposure to surface parasites. For example, individuals that browsed more than grazed had lower nematode infection (Hoste et al., 2001). Goats are able to forage in elevated (above their head) positions and in bipedal stances. In an extensive West African system, goats could browse to an equivalent height as cattle (1 m), and Sanon et al. (2007) reported goats browsing up to a height of 2.1 m. In a small Brazilian study, Pfister et al. (1988) found that goats spent up to 8% of their time feeding on their rear legs despite ample availability of lower level forage. Interestingly, in a Turkish extensive shrubland, there were breed differences, with Turkish Saanens bipedal standing at least twice as much as the other breeds (Tölü et al., 2012).

The natural feeding behavior of goats is markedly different in complexity, duration, and posture compared to the energy-rich, uniform diet fed at ground level that is common in indoor commercial systems. The consequences of failing to offer diet variability and complexity, such as altered daily time budgets (i.e., how they fill in the time they might normally be foraging) or the potential cognitive stimulation arising from the exploration of the feeding environment, need to be considered.

Social Environment

Goats naturally have a complex social structure, with constant formation and dissolution of groups, and a social hierarchy maintained by agonistic and affiliative behaviors. Feral goats (*C. hircus*) live in loose social groups with the composition often changing every hour (Dunbar et al., 1990). A fission–fusion society is thought to result from individuals drifting away as they forage and differences in activity patterns between males and females (Dunbar and Shi, 2008). Group size of free-ranging goats on the Isle of Rhum in Scotland ranged from 1 to 51, but typically consisted of 1 to 3 individuals (Shi et al., 2005). Similar range in group sizes occur in feral goat populations in Scotland (1 to 36 individuals; McDougall, 1975), Hawaii (2 to 25 individuals; Yocum, 1967), and British Columbia, Canada (1 to 100 individuals; Shank, 1972). Social network analysis of the Isle of Rhum feral herd (Stanley and Dunbar, 2013) revealed a core group of 12 to 13 individuals forming a "clique," which the authors suggested was the maximum stable group size. Other authors have also suggested group sizes larger than this are more susceptible to dissolution (Calhim et al., 2006; Dunbar and Shi, 2008).

Although social affiliations could be driven by nutritional demands, Stanley and Dunbar (2013) found that proximity networks were strongly related in poor habitats, suggesting that there may be inherent social benefits of affiliations. A study of partner associations found goats (*C. hircus*) have preferred partners with variable strength and numbers for each individual; partner preferences were measured from affiliative approaches between goats and provided strong evidence that goats seek out and remain close to other specific goats (Stanley and Dunbar, 2013). Given the existence of social bonds and preferential relationships, commercial housing should allow for the development and maintenance of such social cohesion.

Horns appear to have an important role in social behavior. Feral (*C. hircus*) males especially those with the largest horns, are usually dominant over females (Shank, 1972; Shi and Dunbar, 2006); however, horn length also conveys social dominance among females in an extensively managed Spanish herd. (Barroso et al., 2000). Agonistic behavior, such as clashes, rushing, and chasing, occurs when defending sexual partners, during feeding competition (Shi and Dunbar, 2006), or serves to maintain social rank (Shank, 1972). Horns serve purposes in offense and defense during competitive interactions, and their size is an indicator of social status (Geist, 1960). Male goats with large horns have more sexual interactions and displays of overt aggression toward smaller horned males, especially in defense of estrous females (Shank, 1972). Although social dominance is also related to body size and age (Shi and Dunbar, 2006), the poor breeding success of hornless male feral goats, despite their larger body size, highlights the particular significance of horns for goats; hornless goats engaged in fewer aggressive

Figure 1. Horns being used for self-scratching by (a) an Alpine ibex (*C. ibex*) and (b) a milking goat (*C. hircus*) in an extensive alpine management system (Ticino region, Switzerland).

and sexual interactions and have been referred to as "social outcasts" (Shank, 1972). Goats also use their horns to thrash vegetation, which is suggested to be a comfort rather than agonistic behavior when performed simultaneously in small groups of males (Shank, 1972). As has been noted in Alpine ibex (*C. ibex ibex*; Figure 1a), milking goats (*C. hircus*) in an extensive alpine environment were frequently seen using their horns for self-grooming as well (Figure 1b; H. Freeman, personal communication). Finally, there is evidence that horns have a thermoregulatory function in heat exchange between arterial and venous blood as it returns from the horn via the cavernous sinus (Taylor, 1966).

Goats naturally live in much smaller, dynamic groups than what indoor commercial systems might commonly provide; the implications of this divergence are currently unknown. We encourage commercial systems to house goats with consideration for preferential partner associations and opportunity to leave the group if desired. In addition, horns are routinely removed in commercial systems (via cautery disbudding at a young age) to facilitate feeding in current housing designs (British Veterinary Association and Goat Veterinary Society, 2018) and for perceived worker safety. However, horns convey important physical and social information about the individual's dominance rank and are used in a variety of behavioral repertoires. For example, commercially housed dairy goats with horns engaged in less physical contact involving head-butts and chasing compared to hornless goats, perhaps because head-butts are more painful with horns (Aschwanden et al., 2008). Therefore, horn removal in commercial systems should be considered as a significant physical alteration to a goat, rather than the removal of an unnecessary and inconvenient appendage.

Cognitive Ability

The complex and changing foraging and social environments of goats suggest they may have evolved cognitive abilities that have enabled their success. The ability to adapt to different environments requires excellent skills in discrimination, learning, memory retention, and attention to environmental stimuli. A number of studies using housed goats (*C. hircus*) show that these skills are still present after domestication. Discrimination skills are required to distinguish between other conspecifics, predators, or appropriate foraging material. Goats can differentiate between group members on the basis of only their body (Keil et al., 2012) and can identify offspring from their vocalizations (Briefer et al., 2012). Goats integrate visual and auditory cues to identify herd mates, especially for social partners (Pitcher et al., 2017), indicating higher-order cognitive representations of individuals. Domesticated goats can distinguish between positive and negative human facial expressions (Nawroth et al., 2018), can distinguish between different shapes, or can track the movement of objects (reviewed by Nawroth [2017]). Goats can successfully categorize similar symbols and generalize to new symbols (Meyer et al., 2012) and can identify a symbol that did not belong to a group; these abilities were previously attributed only to primates (Roitberg and Franz, 2004). Briefer et al. (2014) also showed goats excelled at learning a complex two-step task of pulling and then lifting a lever to deliver a reward. Importantly, individual goats are reported to seek out cognitive challenges, engaging in a discrimination task even when the reward was freely available (Langbein et al., 2009). This suggests that the cognitive challenge may be rewarding in itself and an important form of stimulation for goats. Individual differences in performance or engagement in cognitive tests may be related to other personality traits. Nawroth et al. (2017) showed that less sociable goats could better identify the location of a hidden object, and less exploratory goats were better at tracking the changing location of a hidden object. A few studies have also tested memory with impressive results. Mothers recognized the unique calls of their kids recorded the previous year (Briefer et al., 2012), and recalled a two-step operant discrimination task from months earlier (Briefer et al., 2014).

Goats are attentive to humans and can use human cues including pointing and body orientation to solve problems such as the location of a reward that requires a detour around a barrier (Nawroth et al., 2016b), and in an object choice task requiring selection of the cup with the hidden reward (Kaminski et al., 2005; Nawroth et al., 2015). They are also known to look toward or physically interact with humans when faced with an unsolvable task (i.e., a sealed container containing food; Nawroth et al., 2016a). As a prey species, this ability may aid in detection and avoidance of predators or in finding food sources. However, studies of social learning in goats found that they more often relied on personal rather than social information in a foraging task (Baciadonna et al., 2013) and did not learn a discrimination task faster after watching another goat perform it (Briefer et al., 2014). The relationship to a competing companion in a foraging task alters decision-making behavior. Kaminski et al. (2006) found that goats that had received aggression from a competing companion were more likely to eat a hidden piece of food over a visible one, whereas goats that had not received aggression were more likely to go for the visible food. These findings suggest that goats may place emphasis on personal information when foraging, but foraging decisions can also be affected by the relationship with competing companions.

Overall, goats have an impressive set of cognitive skills. These cognitive abilities are likely an evolutionary adaptation to succeed in complex and variable social and physical environments. The lack of cognitive challenges in commercial production systems may, therefore, deprive goats of an important, rewarding aspect of their natural behavior and could result in negative affective states. The provision of cognitive stimulation should therefore be regarded as another way that welfare can be improved in indoor commercial settings.

DEVELOPING GOAT HOUSING SYSTEMS THAT MEET NATURAL BEHAVIOR NEEDS

Increasing the opportunity for goats to express natural behaviors in commercial housing systems is not easy or straightforward; however, given the growing concerns from consumers regarding the way that production animals are raised, we suggest it will become an increasingly necessary endeavor. Indeed, evidence for the necessity of promoting naturalness can be seen in the positive view of consumers toward providing animals with outdoor access (Wolf and Tonsor, 2017). There is evidence that indoor goats will still use outdoor space if given the opportunity (Bøe et al., 2012; Stachowicz et al., 2018); however, the intention of this review was to discuss options for improving indoor systems specifically, and therefore, we will now draw on our understanding of the natural behavior of goats in their physical, feeding, and social environments to do so. We provide starting points for how to improve indoor commercial dairy goat housing that better meets the needs of individuals.

Simple environmental improvements to allow for hard and elevated surfaces in goat housing have been considered by a number of authors. There is evidence that indoor-housed domestic goats prefer hard surfaces for lying, such as expanded metal and solid wood (Bøe et al., 2007), and rubber mats and plastic slating (Sutherland et al., 2017). Interestingly, these studies also showed softer surfaces such as straw were the least preferred lying surface (Bøe et al., 2007), and wood shavings were mainly used for elimination rather than for lying (Sutherland et al., 2017). The observation of various wild *Capra* species confirms that there is a definite need to also rest in elevated spaces, such as on rocks (Figure 2a), cliffs, and in caves. Evidence suggests that this behavior is hard-wired for predator avoidance and will be expressed regardless of predator threats. This indicates that domestic goats retain a motivation to seek elevation and hide, and if this behavior is prevented, it may lead to frustration and increased stress. Domestic dairy goats have also been seen to use elevated hard surfaces; this was seen in extensively managed goats (Figure 2b) and in intensively managed indoor goats, where individual preferences were observed for either

Figure 2. Goats displaying similar lying behavior on hard surfaces. (a) Spanish Ibex (*Capra pyrenaica*) in Andalucía, Spain, (b) milking goats (*C. hircus*) in an extensive alpine management system (Ticino region, Switzerland), and (c) milking goats (*C. hircus*) in an intensive indoor management system (MoSAR, INRA, France).

Figure 3. Commercial dairy goat farm (Henry and Anja van der Vlies and family, Ontario, Canada) promoting eye-level feeding posture by elevating the drive alley.

climbing or hiding under a platform structure in their pen (Zobel et al., 2017). The opportunity to climb and feed in elevated spaces increased feeding bout duration and decreased disruption when lying (Aschwanden et al., 2009a). Providing structural elements that allow goats to climb and rest in elevated spaces may, therefore, meet behavioral needs and potentially reduce stress in the group. Such improvements may serve a secondary benefit of providing "vertical space allowance"; this is a significant point when considering the expense necessary to retrofit existing buildings that may not provide enough traditional (horizontal) space allowance.

Feeding management is an important consideration in housing designs because goats are naturally selective browsers. This can be achieved in part by offering elevated feeding surfaces. Providing feed in an elevated rack decreased agonistic behavior and increased feeding time (Ashwanden et al., 2009a). Although a step in front of the feed rail is not necessary for goats to comfortably reach feed (Keil et al., 2017), goats seem to prefer the opportunity to feed in a browsing stance with a step (Neave et al., 2018). A step structure serves a dual purpose as a hard, lying surface in addition to promoting a browsing stance (Figure 2c). Raised feeding surfaces have been incorporated in some indoor commercial systems by raising the drive alley (Figure 3).

An additional consideration is the type of feed provided. The current trend of many intensive systems is to provide high concentrate–forage rations and predominantly one type of forage, which removes the opportunity for feed choice and selection (Rubino et al., 2011). Uniform forage not only limits choice but also negatively affects secondary metabolites (Rubino et al., 2011). Providing goats with feed choice would satisfy their natural browsing and selective foraging behavior, and therefore should be incorporated into commercial feeding systems.

There are also possibilities to provide commercially housed goats with a more natural social environment that allows for smaller groupings, social affiliations, and display and use of horns. On most commercial farms, it is likely impractical to manage goats in small groups of about 12 individuals, but there may be opportunities for goats to "self-group" within larger groups, such as providing increased space allowance (which could be in the form of vertical space) or decreased stocking densities. This would allow individuals to express preferences for or avoidance of particular affiliative or agonistic partners. A number of commercial systems successfully manage goats with horns (Loretz et al., 2004), but they require special management considerations. For instance, horned goats require additional feeding space (Loretz et al., 2004) and feed rail modifications that can help to reduce aggression (Aschwanden et al., 2009b; Hillmann et al., 2014). Providing the opportunity for horned goats to choose feeding locations (such as from a feed rack or platform) may also be beneficial (Aschwanden et al., 2009b). The potential social (e.g., dominance rank) and physical (e.g., thermoregulation and scratching) benefits of horns to the individual goat require a shift toward housing designs that are more accommodating of horned animals.

Throughout this review, we have highlighted the ability of goats to cope with choice and complexity in their physical, feeding, and social environments, which is facilitated by their cognitive abilities. As a consequence, commercial housing environments should ideally address the advanced cognitive skills demonstrated by domestic goats. Without complexity and choice, many of their natural behaviors will not be expressed and what might be considered as species-specific needs will not be satisfied. The physical, feeding, and social improvements to goat housing that are already outlined in this review are likely to add some level of complexity and choice to the goat's environment, which we suggest will in turn help to address the need for cognitive stimulation in commercial housing. This will promote a fuller and more balanced spectrum of natural behavior, improve welfare, and satisfy increasing societal concern about barren intensive production environments.

CONCLUSIONS

Dairy goat housing systems should be designed to promote natural behavior, which will achieve improved animal welfare and potentially improved consumer acceptance of intensive animal production systems. Goats have evolved natural behaviors that influence how they use their environment, how they forage and associate with their social companions. We suggest that the need to cope with complex and choice-filled environments has resulted in goats having advanced cognitive abilities. Although dairy goat housing systems have become streamlined and simplified for feeding and management convenience, indoor housing environments fall short of meeting the natural needs of dairy goats. Simple changes to these environments such as inclusion of opportunities to climb, hide, develop smaller social groups, and interact with different surfaces and heights for both resting and feeding could promote a better quality of life without compromising the production efficiency of modern dairy goat systems.

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