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Effect of social environment during early ontogeny on behaviour and production traits of dairy performance in domestic cattle

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STATEMENT

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Abstract

Under natural conditions cows and their calves live together. In dairy practice, calves are separated from their mothers within hours after birth and then housed individually. Group housing of calves or cow-calf systems may be implemented as rearing systems similar to natural social environment of cattle. But when cows and calves are separated, abrupt weaning as practiced husbandry is stressful for both the cow and her offspring. The aim of this thesis was to investigate how social environment of calves kept on production farms affects the performance and behaviour of cattle, both from the long- and short-term perspective. This Thesis contains three published studies- Study I (Valníčková et al., 2015), Study II (Valníčková et al., 2020), Study III (Stěhulová et al., 2017), and one scientific methodology & data article- Data I (Valníčková et al., 2022). For Study I 40 female calves were allocated to 1 of 4 treatments according to a 2 × 2 factorial design. The treatments were with or without mother during the 4 d after birth and companion housing (single pens or grouped housing in pens of 4 calves between 1 and 8 wk of age). Between 8 and 12 wk of age all calves were housed in groups of 4 calves. Calves were weighted at days 1 and 4 and after weekly up to age 12 wk. Play behaviour of the calves was observed at 2, 5, 8 and 12 wk of age. There were no significant effects of the mother by companion interaction either on the amount of play behaviour in any of the tests or on the body weights of the calves. Presence of the mother after birth did not increase later playfulness, with the exception of higher spontaneous play at 12 wk of age. When calves were housed in groups of 4, they played more in the home pen on wk 2 and 5 than individually housed calves of the same age. In contrast, individually housed calves were more playful during open-field tests and social tests on wk 2 and 5. At 8 wk, single calves that were placed in a new pen with 3 unfamiliar calves played more than twice as much as grouped calves that were just moved to a new pen with familiar companions. These results show that single-housed calves are deprived of natural levels of play, as demonstrated by both their lower spontaneous play behaviour and the higher rebound effect when they are exposed to larger spaces or larger spaces plus companions. Calves that stayed with their mothers for 4 d postpartum grew much better until the end of the second week. After that, grouped calves grew better until wk 10.

Thereafter for Study II all calves used in Study I were managed according to routines of the farm until they became primiparous lactating cows. Data about locomotion, milk yield, milking duration and body weight were collected every milking. Information about calving, inseminations, pregnancy and departure of the animal from the herd/group were added to records. None of the seven performance variables was affected by either the age of separation from the dam or by the type of housing 8 weeks of life. For purposes of Study III we recorded frequency of vocalization and time spent moving in 50 beef cow–calf pairs (27 males and 23 females) immediately after weaning at 151 to 274 d of age. In cows, age of the calf had the strongest effect with mothers of younger calves vocalizing more. Frequency of vocalization was higher in mothers of calves with higher daily weight gain and in non-pregnant mothers. Frequency of the moving was higher in younger cows. Sex of the calf had no effect. In calves, females vocalized and moved more than males and calves with higher daily weight gain also called more. The results of Study I show that brief maternal rearing and group housing independently improve different aspects of performance and welfare of dairy calves, but according to Study II bring no advantage or disadvantage for later performance in female dairy cattle. Datasets collected for purposes of Study I and II and method of data collecting with use of by commercial Precision dairy monitoring systems article were published in article Data I. The results of Study III document that the ability to adaptively adjust mother–young interactions has been preserved in domesticated cattle. In addition male calves cope with weaning distress better than females, which supports the practice that just bull calves are removed from the herd. The current efforts to make weaning less stressful in practical husbandry needs further investigation of various methods of cow-calf dairy systems and level of stress and animal welfare during mutual separation of cows and calves, since we observed strong reactions to separation in both cow and calves separated in ages form 5 to 9 months.

1 Foreword

Under natural conditions, young cattle live in a complex social environment. Immediately after birth, the cow is the calf's first social partner. Later on, the calf gradually spends more time associating with peers and other cows (Edwards and Broom, 1982, Le Neindre and Sourd, 1984). Cattle females spend their whole life in their mother herd (Lazo, 1994) and keep close long-term relationship with their mothers and later their daughters as well (Green et al., 1989). In contrast, on most dairy farms young calves are separated from their mothers a few hours after birth and then housed in individual pens until 8 weeks of age (Staněk et al., 2014). Both the deprivation of maternal care through early separation and the isolation from peers through individual housing may compromise the welfare of the calf. Evidence exists that both brief maternal rearing and group housing may improve welfare and enhance growth in dairy calves (Jensen et al., 1998, Flower and Weary, 2001, Chua et al., 2002) and in females improve subsequent performance (Broucek et al., 2005, Broucek et al., 2006).

Farmers and researchers are investigating possibilities whether and how to change this practice, either through raising calves with their mothers for a few days or longer (Johnsen et al., 2016), or through keeping the calves, after separation from the mother, in groups (or at least in pairs) instead of individually during the milk-feeding period (Costa et al., 2016). Question is if and how social environment of calves kept on production farms affects the performance and behaviour of cattle. It has never been investigated whether an interaction between mother rearing and group housing of calves exists. It is possible that if calves are provided with both components of the natural social environment (mother and peers presence), their growth potential, welfare status and later performance will be particularly positively affected.

In question of rearing of calves with their mothers, their later mutual separation and subsequent artificial weaning is stressful for both the cow (Lynch et al., 2010b, Ungerfeld et al., 2011) and her young (Enríquez et al., 2011). In contrast to natural weaning, the calves are abruptly separated from their mothers, instantly deprived of milk supply, and exposed to a new environment (Weary et al., 2008).The intensity of reaction to mutual separation can vary according to how much it endangers the survival and growth prospects of the calf. Based on the behavioural ecology theory, reaction to mutual separation may be affected by age, weight (Ungerfeld et al., 2009) and sex (Lazo, 1994) of the calf, and current pregnancy (Bateson, 1994) and parity (Pianka and Parker, 1975) of the cow.

It is needed to investigate the independent and the combined effects of the presence of the dam and subsequent group housing on behaviour and growth in calves and on subsequent performance in cows. In question of separation of calves from their mothers, the factors affecting behavioural changes and intensiveness of behavioural signs of stress in cows and calves during separation of calves from their mothers and from mother herd need to be investigated in detail.

2 General Introduction

2.1 The social environment of cattle living under natural conditions

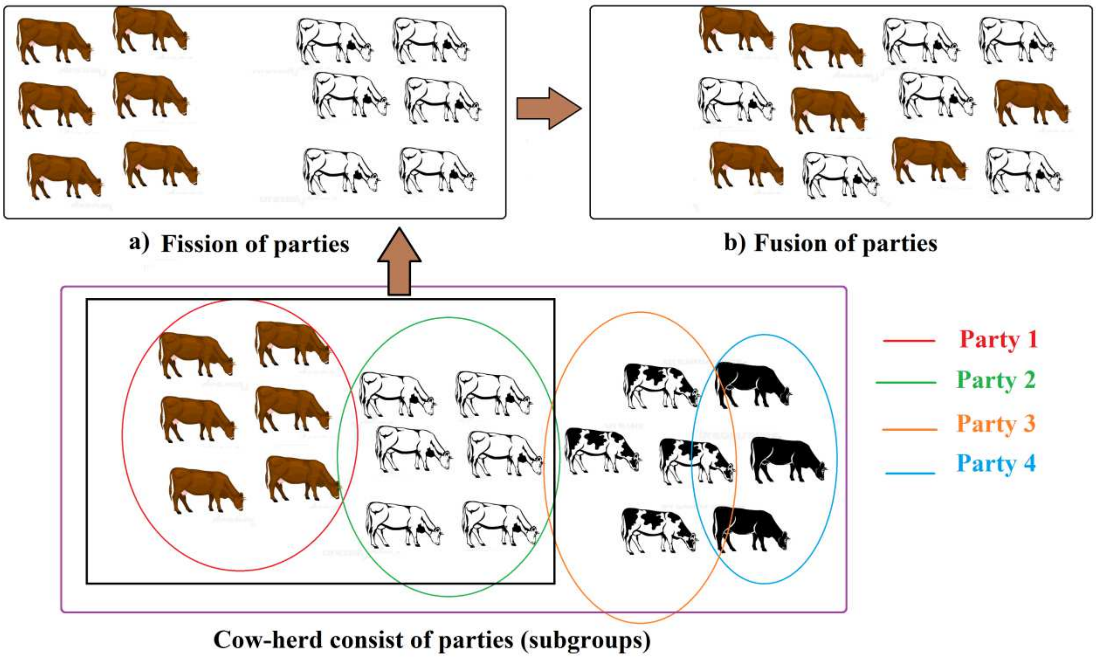
Cattle are social species living in groups created from adult cows and their calves of all sex classes and age groups. Long term associations were described between cows in the herd and their offspring which enhanced the cohesion and stability in the social groups. Lack of the cows' dispersal and strong philopatry in females towards their natal group enhances kinship among the animals within a herd. Cooperation among female kins in a group allows the defence of resources and offsprings (Lazo, 1994).

2.1.1 Social structure of cattle herd

Cattle herds reflect social structure with two levels of organisation based on their size and stability. First (at the lower level), animals form small groups – so called Parties, that show typical fission-fusion behaviour (Lazo, 1994). Formation of parties is a highly dynamic process. The Party size and composition change frequently within the lifetime of all members as parties split (fission) or merge (fusion) (Couzin and Laidre, 2009). The parties are subgroups of much larger herds of cows ("cow-herd"). Cow-herds, the second (higher) level of social organisation, are (unlike Parties) very stable (see picture 1). Cow-herds overall are maintained by long-term social bonds and individual cow-herds do not merge together. The size of a cow-herd is dependent on the availability of food sources as well as on weather or season (Lazo, 1994). In addition, it can be limited by the ability of animals to remember other members of the herd. Cattle are able to remember approximately 50- 70 other individuals they maintain social relationships with (Fraser and Broom, 1997).

Adult bull participation in a cow herd is low and it has marked seasonal character based on the mating season (Lazo, 1994). The main reason for the absence of adult males in the herds might be their exit from the herd after reaching maturity when they are approximately two years old (Green et al., 1989). After bulls leave their mother herd, they usually form all-male bachelor groups or live solitary (Bouissou et al., 2001).

Picture 1: Cow-herd consists of subgroups – so called Parties



As mentioned above, heifers are mostly staying in the herd where they were born in a stable social environment (Lazo, 1994). Long lasting relationship between mothers and their daughters was documented in American bison *(Bison bison)*, animal species related to cattle. Bison mothers and daughters maintained a close relationship even years after the daughter was weaned. Mothers and daughters continued to associate after the mother's next calf was born, though less closely than before. Weaned daughters spent more time in groups with their mothers, approached and followed each other more frequently, and spent more time near each other (Green et al., 1989)The social group of feral cattle hardly ever mixes with components of other herds and mobility of individuals between the herds is minimized. If two or more herds are close to the point where they can merge, a number of agonistic interactions occurs. The main mechanism preventing social and therefore agonistic interactions between the herds is maintenance of exclusive home ranges which do not overlap if possible. The stability of herd home ranges parallels with the stability of the social group, while spatial proximity of the herds is limited by the size and location of the home ranges. It has been documented that in summer and autumn cow-herds occupied just a small portion of their usual annual home ranges and therefore more cases of merging herds and agonistic interactions were recorded (Lazo, 1994). Because the energetic economics of territoriality make it unlikely in big ruminants, the maintenance of the population social structure by dominance relationship rather than by territorial behaviour is expected (Lott, 1991). In this sense some herds are acting like subordinate with respect to other herds (Lazo, 1994).

2.1.2 Social stability of a cow- herd

In conditions without human management new individuals are introduced to the cow- herd just within days after they are born, when they are still calves (Le Neindre and Sourd, 1984, Vitale et al., 1986). A calf is being introduced to the herd by its mother and during the ontogeny is interacting and creating relationships with other members of the herd without an immediate need to establish dominance (Vitale et al., 1986). Females are most likely to stay in the mother herd for their whole life and they don't join any other unfamiliar herd. On the other hand, bulls are usually leaving and tend to join other cow-groups during the mating season (Lazo, 1994) and may change their social environment several times during their life time.

Animals can retreat from their herd just temporarily and these individuals are usually looking for isolation and are not joining any strange herd. Fee-ranged cows prefer to isolate themselves for calving and when they become ill. But this isolation is just temporary and cows stay near their herd (Proudfoot et al., 2014). Proudfoot (2014) observed calving cows of free-range domestic cattle who isolate themselves in a secluded area approximately 1 h before calving. A few hours after calving the cows returned to the herd, or if they became ill, they rather stayed in a secluded area during the time they were sick (Proudfoot et al., 2014). Described cases are only examples of voluntary leaving or joining the cow-herd by specific animals which differ from group changes within the cattle management in the farms. A number of studies suggest that artificial grouping and group changes during the lifetime of the cattle on farms are not in alignment with the social needs of the animals (Von Keyserlingk et al., 2008, Walker et al., 2015, Chebel et al., 2016).

2.1.3 Social hierarchy and affiliative relationships in a cow-herd

Social hierarchy among the members of a cow-herd helps to preserve social stability. Social stability in the cow-herd give opportunity to form complex relationships (Aureli et al., 2002). Social hierarchy of adult animals is being established and maintained through social interactions (Lazo, 1994, Landaeta-Hernández et al., 2013, Šárová et al., 2016). Adult cows spend approximately 2 or 3 hours per day with social interactions (Grant and Albright, 2001). The social hierarchy of cattle is based on dominance. In stable cow-herds the dominance is based mainly on age, where older animals are more dominant (Šárová et al., 2017). In groups of cows which are kept under human management and therefore are not socially stable, dominance is usually based on the body size and weight of the animal, where bigger and heavier animals are more dominant (Landaeta-Hernández et al., 2013, Šárová et al., 2017). Social hierarchy is usually achieved through agonistic interactions among the members of the group (Bouissou et al., 2001), especially if the group is newly formed or the social environment there is unstable. In socially stable groups the social hierarchy is no longer kept through aggressiveness of dominant animals towards the subordinate animals and threatening of subordinate individuals by dominant individuals, but subordinate cows rather avoid conflict with dominant cows (Landaeta-Hernández et al., 2013). For the maintenance of the social hierarchy, the so-called Social licking is important (Bouissou et al., 2001), where one individual is licking the body of another (Boissy et al., 2007). The key role of dominant cows is to keep a stable hierarchy through social licking. Dominant cows often initiate social licking with subordinate animals and dominant cows also lick frequently each other (Šárová et al., 2016).

Cows and calves are able to create strong relationships based on non-random personal preferences (Bøe and Færevik, 2003, Gygax et al., 2010, Gutmann et al., 2015). Long-lasting affiliative relationships in cattle may be built early in life (Bouissou and Andrieu, 1978, Gygax et al., 2010, Gutmann et al., 2015). Long-term familiarity originating from shared experience that happened weeks to years before has strong effects on the intensity of social relationships (Gutmann et al., 2015). Signs of positive social relationship are: spending time in mutual physical proximity, low occurrence of agonistic behaviour, higher number of positive interactions, mutual tolerance in competitive situations (Bouissou et al., 2001) and synchronisation of behaviour (Sato et al., 1987, Gygax et al., 2010, Gutmann et al., 2015). Studies show that preference for social partners is context-dependent. For example, choice of feeding and resting neighbours is not associated and there is no relation between distance of pairs of dairy cows during lying and during feeding. More familiar cows, especially those with a shared long-term experience, were preferential partners for feeding proximity, which may reflect low-level competition rather than friendliness or a positive social relationship. A preferential relationship thus may not reflect an affiliative, but rather a ‘preferred competitor’ relationship (Gutmann et al., 2015). On the other hand, resting together has been interpreted as an indicator of affiliation (Gygax et al., 2010), because resting in spatial proximity is considered a relaxed and content state, and might therefore be an especially suitable indicator for the quality of social relationships (Gutmann et al., 2015).

2.1.4 Socialization of the calf in a natural environment

Calves experience their first social interaction immediately after birth through licking by their mother (Veissier et al., 1990) and their first social partner for the first few days is their mother. A calf is a “hider” in the first 2 to 5 days after birth and lies most of the time alone hidden in vegetation, while its mother is grazing several meters away from the calf and comes to nurse it every few hours (Vitale et al., 1986) approximately 10 times per day (Lidfors, 1996). After the “hider” period, the calf becomes a “follower”, starts to follow the mother and is introduced to other animals from the mother’s herd (Le Neindre and Sourd, 1984). The calf spends time in close contact with its mother during approximately the first two weeks after birth (Grøndahl et al., 2007). During this period, the daily amount of time which the calf spends with its mother is decreasing on account of the increasing time spent with other members of the herd and mainly with other calves (Vitale et al., 1986).

Calves are starting to perform basic social behaviour (for example social licking or parallel play) roughly at 2 weeks of age, and from that point the performance of social behaviour is increasing (Reinhardt et al., 1978, Jensen et al., 1998). Calves which are separated from their mothers immediately after birth can start to socially interact with other calves already on the second day after birth (Duve and Jensen, 2012). Between 2 and 3 weeks of age calves also join so-called “nursery groups” and spend most of the day with a group of other calves which is usually formed within the cow-herd (Vitale et al., 1986, Grøndahl et al., 2007). The “nursery groups”, while attached to adult herds, show a somewhat different and partially independent activity pattern. It is suggested that in cattle, such groups are accompanied by one or more ‘guardian’ females, or even a bull (Sato et al., 1987).

The most performed social activity in the nursery group of calves is play behaviour and synchronised resting (Sato et al., 1987, Grøndahl et al., 2007). Although 2-8 weeks old calves spend just 2% of their daily activity with social interactions (Chua et al., 2002), it was found that young calves create long-lasting affiliative relationships early in life (Bouissou and Andrieu, 1978). Calves as young as 3 months perform synchronised resting, while animals resting less than 20 meters from each other are in positive relationship. Females are more sociable than males (Sato et al., 1987), which can relate to the fact that young bulls are about to leave the mother herd, meanwhile heifers will stay (Lazo, 1994). Evidence of calves forming preferential relationships before 3.5 months of age is known (Raussi et al., 2010). Calves born within 90 days and grown together were documented interacting more also during adulthood, which indicates that individuals with shared youth experience maintain a relationship for years to come (Gutmann et al., 2015).

Approximately at 5 or 6 months of age calves are spacing themselves out from the nursery groups (Sato et al., 1987), meanwhile they decrease play behaviour and begin to show adult behaviour such as affiliative behaviour and aggressive behaviour (Sato and Wood-Gush, 1988). Heifers are new members entering the established herd hierarchy. In the beginning they are ranked lowest in the hierarchy and with time they gradually rise along the hierarchical ladder, which in a stable group is determined mainly by age (Šárová et al., 2013).

2.2 Social environment of dairy cattle

Dairy cattle housing and their social environment in all EU countries and in the Czech Republic as well, are defined by the law (Zákon č. 246/1992 Sb., na ochranu zvířat proti týrání, ve znění pozdějších předpisů, 1992, Council Directive 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes, 1998). According to the minimum standards for dairy cattle housing, it is forbidden in the Czech Republic to keep animals older than 8 weeks in isolation (individual housing), unless less than 6 animals are kept in the facility, or the health condition of the animal or special regulations allow it. is also forbidden to keep animals in such large or so organized groups or in such premises in which the degree or frequency of mutual attacks causes them suffering and which do not allow for natural rest or proper care and in which they are unable to meet their food and water or other needs necessary for their life and health. Livestock must be kept accordingly to species and age category or weight and other specific conditions of entitlement to their protection and welfare according to set minimum standards (Zákon č. 246/1992 Sb., na ochranu zvířat proti týrání, ve znění pozdějších předpisů, 1992).

Most of dairy cattle are currently kept in groups in agreement with their sociality, but the social environment of dairy farms is not usually stable. Due to farm management the animals are moved between groups or the stocking density of the stall can be increased (Rushen et al., 2009), which might differ from the natural social environment of cattle. More detailed information about usual social environment of each dairy cattle category is described in the subsequent chapters.

2.2.1 Social environment of calves

In most European dairy farms, including farms of the Czech Republic, it is common to separate calves from cows within 12 hours after birth and then house them individually (Jensen and Tolstrup, 2021). The reasons why farmers prefer this method of raising calves include better control of colostrum intake and subsequent milk intake, possible reduction of the risk of transmission diseases (mainly respiratory diseases and diarrhoea) in calves and economic aspects due to higher milk yield of their mothers. The reason for the separation of the calf from the mother within hours after birth has also its ethical side. By separating the calf soon after birth, farmers try to avoid separation stress in dairy cows and calves by preventing the establishment of a relationship between the mother and the calf (Beaver et al., 2019). The stress response is possible to observe after mutual separation in both the cow and the calf. Cows and calves often vocalize after separation, show increased activity, have lower food intake and cows show lower occurrence of rumination (Lidfors, 1996, Flower and Weary, 2003, Stěhulová et al., 2008). The calves' response to separation tends to be less intense than in cows (Albright and Arave, 2002).

2.2.1.1 Individual housing of calves

In the EU, including the Czech Republic, individual housing within first 8 weeks after birth is allowed, but when housed individually, calves need to have visual contact between each other (Zákon č. 246/1992 Sb., na ochranu zvířat proti týrání, ve znění pozdějších předpisů, 1992, Council Directive 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes, 1998). In Organic farms of the Czech Republic it is allowed to keep calves individually for only the first 7 days after birth (Zákon č. 242/2000 Sb. o ekologickém zemědělství, ve znění pozdějších předpisů, 2000). Calves can be kept individually for longer than the mentioned period, if there are less than six calves in the farm, or if the calves are sick or show behavioural issues and require individual care (Zákon č. 246/1992 Sb., na ochranu zvířat proti týrání, ve znění pozdějších předpisů, 1992). In 2010, over 60% of all calves were housed individually in the EU (Marcé et al., 2010), and in Czechia it was 96% in 2014 (Staněk et al., 2014). The number of individually housed calves younger than 8 weeks is decreasing in the EU. For instance, in Ireland most of the calves are housed individually just for the period of maximum three weeks after birth (Osawe et al., 2021). Nevertheless, currently the most common housing of calves in their first few weeks is still individual housing (Jensen and Tolstrup, 2021) Individual housing of calves has several advantages compared to housing in a group / pair related mainly to the practical aspect of calves management, as easier manipulation with the calf in smaller space, easier check-up of health condition or better view of food intake (Rushen et al., 2008, Costa et al., 2016), and up to first 5 days after birth correspond also with ethology of cattle, since newborn calves are "hiders" and laying alone in the vegetation during this period of time (Vitale et al., 1986). In addition, it is widely believed that individually housed calves have better health than calves housed in groups (Jensen and Larsen, 2014). Topic of relationship between housing and calf's health is more described in chapter 1.4.

2.2.1.2 Group and pair housing of calves

Calves in this type of housing are placed in a group of two or more calves immediately after their separation from the mother. Group housing can be defined as the rearing of more than two calves together in one pen and pair housing means keeping two calves together in one pen.

In Ireland, Greece and Spain, group housing is ranked as the most frequently used type of housing for dairy calves (Marcé et al., 2010, Jensen and Tolstrup, 2021). Pair housing is the second most frequently used type of housing occurring after individual housing in many European countries. Pair housing is widely used in Denmark, North Macedonia, Poland, Portugal and Slovenia (Jensen and Tolstrup, 2021).

The main disadvantage of group housing may be milk competition and therefore the risk of growth imbalance. Some calves in the groups drink more milk than what is their original ration if they have opportunity to steal milk from peers, while other calves are not fed enough and some calves waste some time by feeding on numerous shifts between milk buckets. Calves in groups ingest the milk faster than calves housed in pairs and calves housed in pairs have lower differences in milk intake between calves, which suggest that the competition for milk is greater in groups than in pairs (Jensen and Budde, 2006).

The main advantage of group and pair housing of calves is not just the possibility of proper social interactions and the development of social behaviour and communication skills (Jensen et al., 1998), but also the access to vaster space and the opportnunity to exercise freely which helps calves develop various types of locomotor behaviour (Jensen et al., 1999, Chua et al., 2002). In addition, group housing of calves can be combined with access to their own or foster mother.

2.2.1.3 Dairy cow-calf systems

In dairy cow-calf systems, calves are housed together, or they have limited possibility of close contact with their own or foster mother. Rearing systems in which calves have access to their own or a foster mother can be successfully applied in intensive dairy farm. Raising calves with mothers or foster cows gives farmers not just the possibility of better self-presentation (since separation of the calf from the mother's sight can be perceived negatively by the public), but raising calves with the dam(s) can also bring benefits for the growth and development of calves (Johnsen et al., 2016). The following methods of calf rearing can be introduced into practice:

Free cow-calf contact systems imply that the cow and her calf are kept together 24 hours a day for an extended period of time (mostly 6 to 12 weeks) during which the cow is milked. Consequently, the cow and calf are free to interact and can nurse at any time (Johnsen et al., 2016). Care taking behaviours by the dam, nursing, and cow–calf bonding which include affiliative behaviours such as licking, rubbing and staying close are important natural behaviours of cattle and are all performed in a free contact system

(Wagenaar and Langhout, 2007). Cows and calves also have a better chance to self-regulate the frequency and timing of suckling bouts which is similar to that of cattle kept under semi natural conditions (Johnsen et al., 2016). Due to the calves' high milk intake and therefore loss of saleable milk for the farmer, separation is done prematurely, for instance at 8–12 weeks, which is long before natural weaning takes place at 8–12 months of age (Reinhardt and Reinhardt, 2009). The main disadvantage of the free contact system is the frequent, high pitched vocalization by cows and calves which occurs during the first days after separation and indicates severe distress (Johnsen et al., 2015a). The sudden shift of reliance on milk to solid feed results in a period of post-weaning low weight gains accompanied by behavioural signs of stress (Johnsen et al., 2016).

Restricted suckling contact or so-called restricted suckling systems imply that the calf is allowed to suckle its own dam during a few short periods daily, often around milking hours. For the rest of the day the cow and the calf are separated. Even in the restricted suckling system the cow–calf pairs show behaviours indicative of recognition and bonding. Upon reunion during the daily nursing, cows and calves rapidly approach, sniff, rub and lick each other. However, more research is needed to clarify how the cow and the calf perceive this limited contact and how this management affects the development of social and cognitive abilities of the calf. There is little published information about the responses of calves and their dams to separation and weaning in restricted suckling systems. According to German farmers using restricted suckling, separation stress is evident and it was reported that the heart rate was higher in the nursed calves during an isolation test compared to calves reared at the automatic feeder. Known disadvantages of restricted suckling systems are limited possibilities for the calf to learn from the dam or other cows and also leading the calves to and from the dams for nursing can be labour intensive depending on how it is managed (Johnsen et al., 2016).

Half day calf-cow contact implies that the cow and the calf are kept together for around 12 hours per day. Cow-calf pairs kept in a half day contact system also perform bonding behaviours (Johnsen et al., 2016). Strong bond is formed even when suckling is prevented by equipping the cow with an udder net, which shows that there is more to the cow–calf bond than a mere nutritional function, and that the mother-offspring relationship is complex in cattle. The udder net may be a viable way of allowing cow-calf contact without suckling and when integrating a milk feeder into a half day contact system (Johnsen et al., 2015b), calves that were trained to use the feeder during the suckling period are more nutritionally independent, which also decreases calves' reaction to the separation from the dam (Johnsen et al., 2015a).

Foster cow system implies that 2–4 calves are kept together and suckle one cow. The cow's own calf may or may not be among the calves. Usually the cow is not milked, but this may vary depending on the stage of lactation and the number of calves per cow. A foster cow system can follow a dam rearing system when calves are dam reared for the first week(s) after birth and then transferred to a foster cow (Johnsen et al., 2016). Advantages of the foster cow system include calves living in groups, having contact with adult cows and performing natural suckling behaviour. Difficulties may occur when a foster cow does not accept, or does not form a bond with, the calves. Although most foster cows accept alien calves (Loberg and Lidfors, 2001), fostered calves often receive less affiliative behaviours from the foster cow compared to the cow's own calf, and the foster cow may often show preference for 1–2 specific calves. Foster cow and calves show behavioural reactions to separation indicative of considerable stress (Loberg et al., 2008), but the application of a two-step weaning using nose flaps may alleviate post separation stress for both the cow and the calf, as it does in beef cattle (Haley et al., 2005).

2.2.2 Social environment of heifers and cows

In many countries, tie-stalls still remain in operation, but this is not ideal for animal welfare due to the constraint of movement and limited space. The cubicle housing system, often called free-stall barn, has been widespread since the 1970s. The grazing of cows is promoted in some global regions. While grazing can be difficult for farmers with large herds and insufficient land around the farm, it is stimulated in some countries due to its benefits for cow health and welfare (Galama et al., 2020). The free-stall cubicle housing system is mostly used in the Czech Republic. Alternatively, wide free-laying areas, grazing system of housing, or deep litter method have been used. In the Czech Republic, tie-stalls were used in less than 4% in 2015 (Doležal and Staněk, 2015).

Mostly, heifers and cows don’t live in stable social environment and are exposed to social stress, which in principle can be of two types. Social stress arises when there is a lack or absence of social contact (social isolation), or as a result of an inappropriate social environment in which the animals are kept. It can be association of individuals who do not suit each other, inducing social instability and fights caused by frequent regrouping or by a high density of animals in a barn or enclosure (Beery and Kaufer, 2015). During the herd turnover, animals are moved between age and production groups according the management of the farm. Cows are frequently regrouped, often 4 or 5 times in a single lactation (Rushen et al., 2009).

From the welfare perspective it is important for cows and heifers to have the option of choosing their partner with whom they can keep a long-term affiliative relationship. If they don’t have this friendship opportunity due to unstable social environment, it may negatively affect their behaviour, production and health (McLean, 2013). It was found that cows create social relationships with other cows during their life on the farm in accord with their natural social needs despite their frequent group changes. The cows after regrouping find animals which they know from the past and affiliate with them (Gutmann et al., 2015). Despite the evidence of maintenance of social relationships between the animals (Gutmann et al., 2015), there is also evidence that regrouping has a negative impact on both behaviour and production. When cows are regrouped, they need to re-establish social relationships using non-physical and physical interactions (Lamb, 1975, Kondo and Hurnik, 1990). The number of aggressive interactions is most frequent immediately after regrouping (Brakel and Leis, 1976, Kondo and Hurnik, 1990). Due to the higher amount of time needed for re-establishing social relationships in a newly formed group after regrouping, cows spent less time eating and less time lying down (Von Keyserlingk et al., 2008). Social competition is greatest at the feed bunk (Val-Laillet et al., 2008), with regrouped cows being more often displaced from the feeding area by other cows (Von Keyserlingk et al., 2008). Agonistic behaviour can negatively affect feeding behaviour, particularly for subordinate cows (DeVries et al., 2004). Furthermore, regrouped cows are less likely to be groomed by a pen mate (Von Keyserlingk et al., 2008). Several researchers have noted a short-term decrease in milk yield for cows that were mixed into a new social group (Brakel and Leis, 1976, Von Keyserlingk et al., 2008), possibly as a result of increased competitive interactions at the feed bunk.

Cows on dairy farms live mostly inside without access to the pasture (Galama et al., 2020), which can lead to an increased stocking density. Increased stocking density can have quite different effects depending on whether it results from the addition of extra animals to a given area, or a reduction in the area available for a given number of animals (Rushen et al., 2009). Cattle are able to maintain social relationships with 50–70 other individuals. In larger groups, it is hard for animals remember others (Fraser and Broom, 1997). Lacking the space to create separate small groups (Lazo, 1994), there are more individuals that need to be dealt with, which in turn leads to a greater variety in dominance relationships and a higher chance of aggressive encounters. Reduced space for a fixed number of animals means that more cows are sharing the same volume of air and the same floor area. In loose housing systems, increased density can result in increased competitive interactions between animals for limited resources such as access to stalls, feeder space, and drinkers (Rushen et al., 2009).

Dairy heifers and cows may face many challenges due to dynamic and unstable social groups and increased density in the barn. It is important to know how social environment in early ontogeny can affect future animal's behaviour, performance and overall welfare in these challenging conditions.

2.3 Effect of social environment during early ontogeny on physiology and behaviour of calves

Under natural conditions, calves grow in a rich social environment of adult animals and calves of both sexes and all ages (Lazo, 1994). A rich social environment enables a proper development of behavioural patterns of social behaviour and other social skills (Broom and Leaver, 1978, Jensen et al., 1997, Veissier et al., 1997, Jensen et al., 1998). In addition, calves can show their preference for the company of a social partner in a small space rather than a spacious enclosure, when they have the opportunity to choose (Jensen et al., 1999). In the environment of intensive dairy farms, calves have usually no or limited options for social company (Jensen and Tolstrup, 2021), despite the rich collection of studies about positive effect of social housing on behaviour and development of calves f. e.(Jensen et al., 1998, Chua et al., 2002, Babu et al., 2004, Tapki, 2007). Since dairy calves in the European Union must have visual contact with other calves by law (Council Directive 98/58/EC of 20 July

1998 concerning the protection of animals kept for farming purposes, 1998), they are experiencing partial isolation during their ontogeny period, which affects mammals less negatively than full isolation (Harlow et al., 1965, Yarnell et al., 2015). Nevertheless, animal species which live naturally in rich social environment, like cattle, can experience partial social isolation as a stressor (Yarnell et al., 2015). Partial isolation can in calves be defined as absence or low frequency of social interactions with other individuals of the same species during longer period of ontogeny (Gottman, 1977).

Non-stable social environment might be stressful for calves, as well as heifers and cows, and cause social stress (Beery and Kaufer, 2015). Social stress in calves can be displayed for example by high occurrence of aggression and food competition which was documented in dynamic groups where calves moved often between the age groups (Costa et al., 2016). The effects of different types of social environment on behaviour and physiological and performance traits are described in more detail in the subsequent chapters.

2.3.1 Effect of social housing of calves on their behaviour

2.3.1.1 Effect of housing with peers on calf's behaviour

Calves housed with peers are more active compared to the calves housed in single housing, which leads to a better development of the musculoskeletal system and locomotor behaviour. On the other hand, individually housed calves are housed usually in smaller space and therefore they spend more time while laying and with resting behaviour, which can have a negative impact on the development of the musculoskeletal system and locomotor behaviour (Jensen et al., 1999, Chua et al., 2002).

Individually housed calves show higher reactivity (i.e. frequency of defecation), lower activity in comparison to pair housed calves (De Paula Vieira et al., 2012) and impaired cognitive performance (Gaillard et al., 2014). Individually housed calves show higher frequency of play behaviour in novel environment and during an encounter with an unfamiliar calf as well, meanwhile group-housed calves play less when exposed to such novel situations (Jensen et al., 1999, Jensen and Kyhn, 2000, Duve and Jensen, 2011, Rushen and de Passillé, 2014). The described differences demonstrate a powerful rebound effect (Dawkins, 1988) in play behaviour when calves housed in individual pens or with peers are exposed to larger novel space and unknown companions.

Elements of social play and parallel play are completely missing in individual housing, which can be caused by insufficient social stimulation (Jensen et al., 1998). Play behaviour is affected not just by the presence of a companion and a play partner, but also by the size of the space where the play can be performed. Locomotor play in the paddock with an area of 1.5 m^2 was minimal. The frequency and performance of locomotor play behaviour positively correlated with space increased up to an area of 4 m^2. Within this area of the paddock, play behaviour included the same fully developed elements as a calf living in natural conditions shows (Jensen and Kyhn, 2000). While calves housed individually show limited development of play behaviour if they are housed in a paddock smaller than 4m^2 (Jensen and Kyhn, 2000), calves housed in groups show a richer repertoire and higher frequency of play even while they are housed in smaller space (Jensen et al., 1998).

When examining the psychological condition of individually versus pair-housed calves, it was found that paired-housed calves are more optimistic and more positive in comparison to individually housed calves. The access to a social partner has a positive effect on the mental state of the calves (Bučková et al., 2019).

The advantage of individual housing of calves for the farmers is a closer relationship of calves with humans, since calves raised in individual housing during their early ontogeny period maintain a closer contact with humans and show less fear towards humans than calves raised in group housing (Chua et al., 2002).

2.3.1.2 Effect of housing with a dam on calf's behaviour

Calves raised with cows have increased social competences and show lower cardiac stress reaction to a combined isolation-novel object-confrontation test (Buchli et al., 2017). Increased social competence in calves means for example a faster developed ability to make contact with peers and be more active upon the first encounter with an unknown individual (Weary and Chua, 2000, Flower and Weary, 2001). Calves housed with a mother or foster cow also have a lower incidence of abnormal behaviour such as cross-suckling (Johnsen et al., 2016) and higher intake of non-dairy solid food, which persists even after the separation from the mother (Krohn et al., 1999).

2.3.1.3 Long- term effect of social housing of calves on their behaviour

Most of the work to date in dairy calves has focused on the effects of social isolation during the milk-feeding period, the weaning period, and the days immediately following weaning. The lack of work on longer-term effects is likely due to the time required and the challenges associated with maintaining adequate controls (Costa et al., 2016).

Previously group housed calves cope better with the new social environment, which is reflected in lower levels of agonistic behaviour when they are later in life introduced to a new social environment within the herd turnover (Jensen et al., 1997, Veissier et al., 1997). Calves that were allowed to develop their social skills during the early ontogeny via social housing were able to secure better their position in the hierarchy later in adulthood (Broom and Leaver, 1978). Calves raised in groups with other calves develop faster their ability to make contact with peers and be more active upon the first encounter with an unknown individual (Weary and Chua, 2000, Flower and Weary, 2001), which is significantly reflected in the psychological well-being of such reared animals and of the entire herd in further life and adulthood (Le Neindre and Sourd, 1984).

Calves raised together with a foster cow are later in life dominant over the calves raised without a cow (Le Neindre and Sourd, 1984). Calves reared with a foster cow show more pronounced maternal behaviour and more locomotion and exploration during isolation tests years later (Le Neindre, 1989). Also dam-reared calves transition better into the lactating herd, suggesting that social housing of calves may enhance social skills that are useful later in life (Wagner et al., 2012).

2.3.2 Effect of social housing of calves on their health and performance

2.3.2.1 Effect of housing with peers on calf’s health and performance

There is still a concern among farmers that calves housed in groups have a higher incidence of the diseases, which may have a negative impact on animal welfare and the economy of the entire farm. However, studies examining the health condition of calves in different types of housing are fundamentally in disagreement and the statement that calves reared in groups are more frequently ill than individually housed calves is not valid generally (Valníčková and Šárová, 2017). The topic of calf health is broad and complex and in addition to the social environment, other risk factors need to be taken into account, such as inadequate management (e. g. insufficient amount and quality of milk, methods of calf feeding, exposure of animals to painful procedures, inappropriate manipulation, etc.) (Reimus et al., 2020), inappropriate microclimate (Roland et al., 2016), poor immune condition of calves (Klein-Jöbstl et al., 2014), insufficient control of the health condition of animals (Gulliksen et al., 2009) or inadequate hygienic conditions (Klein-Jöbstl et al., 2014).

From the social perspective, the health condition or mortality of calves housed with peers may be negatively affected by too high a number of calves in the group (Svensson and Liberg, 2006), too vast an age gap between the calves housed together (Pedersen et al., 2009, Marcé et al., 2010), and stress caused by moves between the age groups and transport (Pedersen et al., 2009, Walker et al., 2015). In case of larger groups, the age when calves are grouped together is decisive (Svensson and Liberg, 2006, Curtis et al., 2016).

Calves housed in groups may compete for milk and run the risk of great differences in weight gain among calves in the group (Jensen and Budde, 2006). On the other hand, calves housed with peers start eating solid food earlier and in larger quantities (Chua et al., 2002, Babu et al., 2004, Hepola et al., 2006) and begin to ruminate earlier and more often than calves housed individually (Babu et al., 2004, Hepola et al., 2006). Higher weight gain in group and pair housed calves may be the result of (Tapki, 2007, Costa et al., 2016, Pempek et al., 2016) higher dry matter intake (Costa et al., 2016)and better food conversion too (Babu et al., 2004, Tapki, 2007). In addition, group or paired housed calves transit better to solid food during weaning from milk, as evidenced by their higher weight after weaning (Chua et al., 2002, Miller-Cushon and De Vries, 2016, Pempek et al., 2016).

2.3.2.2 Effect of housing with a dam on calf's health and performance

The advantage of later separation of calves from their mother is higher colostrum intake than in calves who are separated from the mothers immediately after birth (Krohn et al., 1999). Moreover, nursing from the dam increases the amount of IgG and IgM absorbed from the colostrum (Quigley et al., 1995). But if the mother has little or low quality colostrum, calves may be at risk of transmission of passive immunity failure (Franklin et al., 2003, Lora et al., 2019), which might cause health problems in some calves, such as diarrhoea (Svensson et al., 2003). This means that newborn calves need to be under control even if they are left with their mothers and intake of sufficient amount of good quality colostrum must be ensured if a calf does not drink enough colostrum from its mother (Beaver et al., 2019, Lora et al., 2019).

In the period which calves spent with their mother, calves with their mother show from 2 to 3 times greater weight gain compared to calves housed without their mothers. Increased weight gain disappears after separation of calf from its mother (Metz, 1987, Krohn et al., 1999, Flower and Weary, 2001). The weight gain of calves housed with a foster cow is uneven and the growth and weight of calves in a group of nursing cows can vary greatly. The difference between growth and weight gain of calves especially depends on the milk production of the nursing cow (Johnsen et al., 2016). In calves raised with their mothers, a lower incidence of diseases such as diarrhoea and respiratory diseases has been found (Flower and Weary, 2001, Flower and Weary, 2003), along with lower mortality than calves reared without mothers (Rushen et al., 2008).

The combination of weaning, maternal separation, and transportation resulted in higher mortality in beef calves using a secondary bacterial challenge model that included bovine herpesvirus-1 followed by *Mannheimia haemolytica (Hodgson et al., 2012)*. This example of a variety of possible social stressors combined demonstrates clearly the overall impact of social stressors on the health of calves.

2.3.2.3 Long- term effect of social housing of calves on their health and performance

There is still a lack of research on the long-term effects of social housing and possible social stress of calves on their health and performance. But existing research shows that when calves were kept with their mothers for one week after birth, they later showed larger milk production during first lactation. Also calves reared with foster cows up to 8 weeks of age had a higher weight gain during this time and later tended to have the highest production of milk during the first lactation (Broucek et al., 2006).

In scientific literature concerning human health, extensive research on the topic has determined that social factors play a key role in mediating disease risk (Proudfoot and Habing, 2015) and social factors that are thought to cause stress predispose people to non-specific, negative health outcomes (Uchino, 2006, Kroenke et al., 2013). Given the strength of the associations between disease and social stress in humans, comparable associations between social factors and disease risk seem likely in farm animals. Like humans, cattle breeds reared for food production are social and they have adapted to living in complex social networks. Group dynamics of cattle housed in intensive farms can be highly variable depending on the management and housing practices used on the farm. The impact of these practices on disease incidence is likely to be partly mediated through previous or current social stress that the animal was or is exposed to (Proudfoot and Habing, 2015). Social deprivation during sensitive early periods in development can impact the long term stress response in a variety of species, such as rodents (Hall, 1998) or pigs (Kanitz et al., 2004). Socially isolated young piglets decreased locomotion during isolation and had increased basal cortisol compared to control piglets that were housed with their dam. Six weeks after the treatment, isolated piglets had higher basal ACTH concentrations and higher glucocorticoid receptor binding in the hippocampus compared to controls, suggesting long-term effects on hypothalamic–pituitary–adrenal (HPA) activity (Kanitz et al., 2004). HPA controls reactions to stress and regulates many body processes, including digestion, the immune system, mood and emotions, sexuality, and energy storage and expenditure (Selye, 1976). As an example of immune responses of animals with stronger physiological stress reactions, it is possible to mention the research of Hopster et al. (1998), who categorized dairy cows according to high and low plasma cortisol response after experiencing social isolation. One year later, the cows underwent an intramammary endotoxin challenge and only those cows that were previously high-cortisol responders developed a fever. In addition, cows with high-cortisol response tended to produce less milk than cows with low-cortisol response (Hopster et al., 1998).

2.4 Play behaviour of calves

Impoverished social environment during early ontogeny may limit the opportunity or motivation to play, therefore one possible approach to measure the welfare of calves is to record their play behaviour. Calves spend between 1 and 10%

of their daily activity with play behaviour. Play behaviour could be described as structure transformation and functional testing of behavioural models, or individual behavioural elements (Phillips, 2002). The principal hypothesis about play behaviour is that its function is to rehearse behavioural sequences in which animals lose control over their locomotion, position or sensory/spatial input and need to regain these faculties quickly. Due to play behaviour animals learn to master behavioural and motorical skills fast and manage complicated situations that individuals may encounter in life. Through play, the individual has an opportunity to discover and practice muscular system functions and develop motor versatility. The ability to cope quickly with the actions of some atypical movements could mean a matter of life and death during the attack of a predator. Besides the locomotor versatility, animals learn during play how to deal with the emotional aspect of being surprised, temporarily disoriented or disabled and gain the ability to develop emotional flexibility (Špinka, 2001). Play behaviour in which a calf comes into contact with adults and other calves contributes to a smooth integration of the calf into the group (Phillips, 2002). In this manner, the calf learns to communicate and cope with future changes in social hierarchy and the emotions that these changes bring (Špinka, 2001).

2.4.1 Types of play behaviour

Three main types of play behaviour are distinguished in calves: locomotor play, social play and object play (Jensen et al., 1998, Jensen and Kyhn, 2000).

Locomotor play is not focused on any object and individuals do not interact with each other (Bekoff, 1972). Locomotor play contains playful movements, such as galloping, jumps, buck-kicks, head shaking, etc. (Jensen et al., 1998, Jensen and Kyhn, 2000)

In **Social play**, at least two partners are involved. Play partners have a social relationship and no real agonistic behaviour is shown during the play (Bekoff, 1972), although play can simulate fight (Jensen et al., 1998, Jensen and Kyhn, 2000). Social play can be further divided into social locomotor play (so-called parallel game, where there is no interaction between animals, but can occur in more than one individual at the same time, e.g. parallel gallop, parallel jumps, etc.), play fights (e.g. butting) and play mounts (pretending sexual behaviour) (Jensen et al., 1998).

In **Object play** animals play by manipulating objects. These games include, for example, play with straw (Jensen et al., 1998).

Exploration (exploratory behaviour) may occur as part of the play or exploration may smoothly turn into play behaviour. Although play behaviour and exploration have a lot in common, they also have three main points in which they differ. First, the purpose of exploration is to avoid problems (through the acquisition of information and knowledge), while through the play behaviour the calf learns how to get out of problems (through the acquisition of skills). Second, while the game may include targeted self-handicapping in the challenges that calf overcomes during the play, self-handicapping never occurs in exploration. The third, fundamental difference is in the state of mind of the animal. While during the play behaviour the individual is more relaxed and in a relaxed state, during exploration the animal is in tension and apprehension of the possible danger that the object of research may bring (Špinka, 2001).

2.4.2 Ontogeny of play behaviour

When a calf is born, the first type of play behaviour observed is locomotor play (Jensen et al., 1998), which was observed already 3 hours after birth (Kiley-Worthington and Plain, 1983). Calves can play with adults at an early age, as the mother is an important stimulant of play behaviour for a young calf. (Phillips, 2002). However, when calves begin to associate in nursery groups, the peers become their main play partners (Vitale et al., 1986, Sato et al., 1987). All elements of social play are fully developed in most calves after the second week of age. Social play of dairy calves then increases during the first seven weeks of age, whereafter its frequency and intensity decrease again. Decrease of the play behaviour around the 8th week of age might correspond with weaning from the milk and cut-off milk supply (Jensen et al., 1999).

2.4.3 Play behaviour and welfare of calves

The play behaviour takes place only in a safe environment without tension, when the animal is relaxed and in a relaxed state (Špinka, 2001). Vital needs attenuate play behaviour because they have absolute priority. Animals do not play when they are hungry or in danger (Phillips, 2002). Calves start to play when their primary needs are fulfilled (Jensen and Kyhn, 2000). Play behaviour can be considered a direct indicator of a good psychosomatic condition of the animal (Dannemann et al., 1985). To support this theory, it is possible to mention the observation of lower frequency of play in calves housed without bedding compared to calves housed with straw bedding (Albright and Arave, 2002), or lower frequency of play observed in calves housed in a stable with lower light intensity compared to a stable with sufficient lighting intensity (Dannemann et al., 1985). There are also some dissident cases. If an animal is prevented from performing play behaviour that a less restricted member of its species would perform, or unable to perform the full repertoire of play behaviour shown in unrestricted conditions (e.g. during lack of social interaction or space) (Dawkins, 1988), the intensity of play significantly increases after it moves to a more suitable environment (e.g. bigger space, with social partner), where a new opportunity to play arises. The quality and quantity of play behaviour may reflect the welfare or emotional state of the calves (Held and Špinka, 2011).

2.5 Weaning

During the process of weaning in the farms, calves are separated from their dams earlier than the natural time of weaning from the milk and possible separation from the mother and her herd would occur (Weary et al., 2008). This artificial weaning connected with separation from the mother and herd is stressful for both: the cow (Lynch et al., 2010b, Ungerfeld et al., 2011) and her young (Lynch et al., 2010a). During abrupt weaning and separation of calf from the mother, the cow and the calf show behavioural signs of distress such as increased vocalization and activity (Stěhulová et al., 2008). According to the behavioural ecology theory, the reaction to separation should vary according to how much it endangers the survival and growth prospects of the calf (Ungerfeld et al., 2009). In another theory, the reaction to weaning and mainly to the separation from mother can also vary between the sexes of weaned calves. Since female progeny stay in the herd for the whole life, (Lazo, 1994) continuous maternal contact is more important for them and abrupt weaning along with change of social environment can potentially cause more distress. Meanwhile, bulls eventually leave their maternal herd (Lazo, 1994) and are evolutionarily prepared to experience changes of their social environment. This theory is not supported enough by published scientific articles and more research needs to be done to find out if male calves show lower stress response to separation from the mother compared to female calves. Research on this topic is therefore one of the objectives of this thesis.

Natural and spontaneous weaning is often a long-term, gradual, and not very comfortable process, when declining willingness of the female to subsidize the growing young offspring with milk usually clashes with the effort of the offspring to obtain milk from the mother (Trivers, 1974, Jensen, 2001). The outcome should be an optimal compromise that ensures sufficient dairy nutrition for the young, but does not exhaust the mother. The amount of provided milk is decreasing with time, as the calf's dependence on mother's milk is lower and its effort to obtain milk from the mother is decreasing as reaction to the mother's restraint of nursing (Jensen, 2001). In the natural social environment, after weaning, the dam stops to provide milk to the offspring, but not social support. The specific relationship between mother and offspring persists until the calf leaves the maternal group. In species where the offsprings remain in the herd where they were born, the relationship between the mother and her offspring persists over their whole life (Le Neindre and Sourd, 1984). The relationship between a mother and her daughters persists for many years after the mother has weaned them, as has been documented, for example, in American bison (*Bison bison*), a related species of domestic cattle. The bond between mother and daughter is not broken even by the birth of the next calf. With the birth of another sibling, the mother and daughter may become more distant from each other socially, but after weaning of the sibling, the mother and older daughter often resume their relationship (Green et al., 1989, Green, 1993).

Natural spontaneous weaning in cattle is starting around the 4th month of calf age, when the mother begins to reject some calf requests for suckling. However, the actual weaning of the calf from milk occurs much later – between the 8th and 10th month of the calf's age, if the mother is pregnant again. The non-pregnant cows wean their calves from milk usually later (Reinhardt and Reinhardt, 1981). The process and the result of weaning are in addition affected by many other factors, especially by the condition of the mother and offspring(s) or environmental conditions (Le Neindre and Sourd, 1984).

2.6 Precision dairy monitoring technologies

Precision dairy technologies use automated, mechanized technologies toward refinement of dairy management processes, procedures, or information collection (Bewley, 2016). Since the 1980s, efforts have been made to develop sensors that measure a parameter from an individual cow. The development started with individual cow recognition and was followed by sensors that measure the electrical conductivity of milk and pedometers that measure activity (Rutten et al., 2013). These efforts resulted within decades into development of Precision dairy monitoring technologies. Precision dairy monitoring technologies monitor behavioural, physiological, or production indicators not just to collect actual raw information about production, physiology and movement (Stone, 2020) of each animal, but mainly to detect individual animal disease, oestrus, welfare (Stone et al., 2017), or impending calving. Many precision dairy monitoring technologies are commercially available and are being used in research and on farms (Borchers et al., 2017). Precision dairy monitoring technologies can be placed on or inside the cow and many technologies are now available in the parlour, in robots, and in an exit or feed alley. Until recently, most precision dairy monitoring technologies worked just with 3-axis accelerometers with different algorithms applied, but advanced imaging and different devices became more commonly used (Stone, 2020). In past times, precision dairy monitoring technologies evaluations focused mainly on automated oestrus detection, aimed to supplement or replace visual oestrus detection (Dolecheck et al., 2015). However, precision dairy monitoring technologies also have the potential to detect various events (such as for example disease, parturition, or oestrus) early, maximize individual animal potential (Stone, 2020) and it provides hope for further improvements in both cow and farmer well-being (Bewley, 2016).

Working principles with precision dairy monitoring technologies can be split into four levels (Rutten et al., 2013): Level I contains measurement (quantification), which simply tells the user what has occurred (i.e., the number of steps taken, kg of milk produced, hour spent lying down) without drawing any conclusions. Quantification is the first step in technology development and is critical for the development of more sophisticated systems. Quantification can be used as raw data, allowing users to decide for themselves how the data should be interpreted (Rutten et al., 2013, Eckelkamp, 2019).

Level II: interpretation of measurements (classification) analyses the collected measurements with algorithms to inform the user about the cow's current state (i.e., oestrus, illness) and allows the user to make informed decisions (Rutten et al., 2013, Eckelkamp, 2019).

Level III: integration of interpretation with other information connected with Level IV: decision support or creation would mean the system combined the measured information with other information (i.e., herd records, weather data, additional cow measurements, or economic data) and provided a recommendation to the user or formulated a decision based on the recommendation (Rutten et al., 2013, Eckelkamp, 2019). For example, accelerometer behaviour data during the transition period could be combined with herd management software information. Based on information from that cow's current and previous lactations, a risk assessment could be provided for metabolic disorders (Nordlund and Cook, 2004, Vergara et al., 2014).

Researchers are actively pursuing validation of and research on commercially available precision dairy monitoring technologies and numerous publications on this topic are available (Stone, 2020). Currently a wide range of commercially used products are available on the market. Afimilk Ltd. Is one of the companies producing precision dairy monitoring technologies (Chanvallon et al., 2014) and technologies of this company were used for the data collection in this thesis. Their systems have sensors, utilities and software that have been developed with the capability to measure and evaluate variables for individual cows (Brandt et al., 2010, Rutten et al., 2013, Chanvallon et al., 2014). Variables which were observed and collected by precision dairy monitoring technologies within this Thesis will be described closer in the next chapters about milk yield and milking time, milk electrical conductivity, activity and body weight.

2.6.1 Milk yield and milking time

Daily milk yield (measured in kilograms of milk) may be an indicator of udder health (together with milk conductivity sensors) or may serve (together with other variables) as an indicator of oestrus (Maltz et al., 1997), since cows have lower milk yield when they are in oestrus (Firk et al., 2002). Milk yield can be used also for detection of systematic health disorders. For example multiparous cows show lower milk yield when they suffer postpartum diseases such a metritis, hyperketonemia, and hypocalcemia (Tsai et al., 2021). One approach used in on-farm milk monitoring software is to use the cow as her own control by calculating her 10-days rolling average and comparing her performance at subsequent milking to that average (Lukas et al., 2009). Decrease of milk yield related to a health disorder can be observed as early as 10 days before the day of diagnosis. The average magnitude of the negative effect is less than 10% up to 3 days before the day of diagnosis (Edwards and Tozer, 2004). Diseases and health disorders in lactating cows can be followed by a great loss of milk yield as well. On the day of diagnosis, for example diarrhoea, systemic mastitis, ketosis and milk fever might be associated with high reduction in milk production (4.1–25.7 kg) and decreased milk yield can be detected even 140 days after the diagnosis (Bareille et al., 2003). Milk yield is also decreasing when the cow is experiencing social stress, probably due to decreased food intake and rumination activity. Lower milk yield was documented after introducing the cow to an unknown social environment, in which cows were kept in groups with increased stocking density. And on the contrary, when primiparous cows were separated from older, multiparous cows, their milk yield as well as food intake and rumination activity increased (Grant and Albright, 2001). Cows which moved from a tie stall to a free stall and therefore met new unknown individuals, produced 23.3% less milk on the first day following the transfer than on the last day prior to moving. Loss of milk was gradually reduced and maximum production was achieved again on the 14th day after the transfer (Broucek et al., 2017). Reduced milk yield was documented also in primiparous cows that remained in the group from which some animals were removed. Those remaining animals rose in the social rank due to their need to re-establish social hierarchy in the group, through agonistic interactions with other remaining group members. Milk yield in this case lasted for 1 week after regrouping (Hasegawa et al., 1997).

Milking time (measured in seconds) is one of the characteristics in the trait complex of milkability (Gäde et al., 2006). Milkability is defined as the ability of an animal to give a regular, complete, and rapid milk secretion by the mammary gland in response to a proper milking technique (Boselli et al., 2020). Milkability is characterized by the average milk flow rate, maximum milk flow rate and milking time (Gäde et al., 2006). Increased milk flow and decreased milking time, respectively, mean a decrease in milking labour time, and labour accounts for a large fraction of the total costs of milk production. In an automatic milking system, the reduction of total milking time per milking per cow means an increase in the capacity of the automatic milking system (Groen et al., 1997, Gäde et al., 2006). But also too short milking time might be connected with too high teat compression intensity and therefore negative impact on health of the udder. On the contrary, increased milking time in connection with lower teat compression intensity may be associated with a lower incidence of teat-end callosity and decrease in composite milk somatic cell count (Nørstebø et al., 2019). Milking time can be related to the stress level of milked animals too. It has been established that the cows with high stress resistance were milked in double-quick time compared to the cows with low stress resistance (Chernenko et al., 2018). Also social isolation of ewes shortly before milking and disturbing of animals during milking induces stress on experimental ewes, which negatively influences milking efficiency including lower milk yield and shortening milking time, which can be mainly explained by the inhibition or delay of oxytocin secretion during milking under stress (Tančin et al., 2015).

2.6.2 Milk electrical conductivity

The electrical conductivity is determined by the concentration of anions and cations. If the cow suffers from mastitis, the concentration of Na^+ and Cl^- in the milk increases, which leads to increased electrical conductivity of milk from the infected quarter (Kitchen, 1981) and therefore together with other measurements (i.e. milk yield) it might be a good indicator of udder health (Maltz et al., 1997). Electrical conductivity of milk has been the most studied sensor technique for mastitis detection (Rutten et al., 2013). Automatic milk monitoring of electrical conductivity may help detect the disease early, reducing pain and production losses associated with the disease (Bewley, 2016).

Most automatic milking systems have electrical conductivity sensors incorporated for measuring electrical conductivity during milking (in-line) (Norberg et al., 2004). To get reliable information about electrical conductivity of milk during one milking, the milk is checked by sensors when a certain amount of milk is milked (for example every 200 cubic centimetres), while the milk flows through the milk meter

(Tinsky et al., 1995). Electrical conductivity has mainly been expressed as a maximum value for each quarter or each milking (Maatje et al., 1992, de Mol et al., 1999). On the other hand conductivity measurements are less effective in detecting mastitis in infected quarters (around 69%) (Gebre-Egziabher et al., 1979), and increased electrical conductivity does not definitively mean a cow has mastitis. However, if the electrical conductivity of the milk has risen above a predetermined threshold, then whoever in charge or the milkman is informed of that change (Hogeveen et al., 2013) and can investigate such a change.

2.6.3 Activity

In Precision dairy farming technologies, activity (measured by the number of steps) is usually included as part of automated oestrus detection technologies, which are an available alternative to supplement or replace visual oestrus detection. Parameters with a potential for automated oestrus detection include mounting events, activity level, lying time, rumination events, blood or milk progesterone levels, feeding time, body temperature, and more. Oestrus-related changes in activity level have been quantified repeatedly (Dolecheck et al., 2015), since restlessness is an important external indicator for incidence of oestrus with activity values of a reference period (Firk et al., 2002). To determine the accuracy of a specific automated activity monitoring technology, events identified by the technology algorithm (a set of criteria used to determine “oestrus” or other event detectable by activity) are compared with a gold standard such as visual observation, ultrasonography, blood or milk progesterone levels, etc. or a combination of these (Firk et al., 2002). But activity can be used as an algorithm variable for prediction of more events than just oestrus detection. Changes in activity can help to predict for example oncoming calving (Borchers et al., 2017), to detect postpartum metabolic disorders (Eckelkamp, 2019, Tsai et al., 2021), and disease detection (Eckelkamp, 2019) such as lameness (Mazrier et al., 2006) or heat stress (Stone et al., 2017). Activity can differ within the breeds and parity of cows. Primiparous cows may have been displaced from the feed bunk more often, they may have to walk from the feed bunk to the free stalls more often than their dominant counterparts, and thus their activity may be greater than multiparous cows (Stone et al., 2017), which leads to the idea of using activity level also for increased agonistic behaviour detection.

Electronic pedometers are available for automatically recorded step activity of an animal (Firk et al., 2002). Pedometers used for livestock activity measurement are within a wireless sensor network, where signal is transmitted via Radio frequency energy, which can be transmitted from one source to many receivers (energy harvester sensors nodes). The pedometer usually contains an accelerometer and a gyroscope (Beng et al., 2016), which can be for example based on mercury that is turned off and on by the movement of the cow. Pedometers can be attached on the neck or a leg. Registration of the pedometer values is commonly performed during visits at a concentrate feeder or at the entrance of the milking parlour (Firk et al., 2002) through a link whenever the pedometer appears within the range of the reader or every previously defined period of time, e.g. every hour (Brehme et al., 2008, Beng et al., 2016).

2.6.4 Body weight

The body weight of the dairy cow measured on-line automatically on a daily basis can be obtained in a variety of forms such as by walk-through scales, or by stationary electronic scales where the cow is stopped for a few seconds in the outlet path from the milking parlour (Maltz et al., 1997).

It is often claimed of daily changes in live weight in dairy cattle that they could serve as useful information for both the diagnosis to detect temporary physiological disorders such a health problems, for feed management by characterizing the physiological status of the cow and for feeding cows according to performance, in order to prevent undesired fattening (Maltz et al., 1997).

From the analysis of daily data of individual cows it is obvious that differences of 10 to 15% of live weight between successive days are normal fluctuations, but a daily 60-kg weight drop in a 600-kg cow should set off an alarm, because this can happen only due to a severe physiological disorder. (Maltz et al., 1997). It was also found that multiparous cows show lower body weight when they suffer postpartum diseases like metritis, hyperketonemia, and hypocalcemia (Tsai et al., 2021). During the experiments with daily body weight observation approximately 50% of health problems were identified by body weight changes up to 3 days prior to health problems clinical manifestation and visual detection (Maltz, 1997). It is due to physiological disorders leading to loss of appetite or not feeding because of extended activity, and therefore they are likely to be detectable by a significant temporary reduction in body weight if frequent measurements are taken (Maltz et al., 1997). Weight loss may occur while the animal is exposed to social stress, because cows reduce food intake and rumination when they are exposed to a new social environment and unknown animals (Grant and Albright, 2001, Schirmann et al., 2011) or live in a group with significantly increased stocking density (Grant and Albright, 2001).

3 Scientific Hypothesis and Objectives

The aim of this thesis was to investigate how the social environment of calves kept on production farms affects the performance and behaviour of cattle, both from the long- and short-term perspective.

This Thesis contains three published studies- Study I (Valníčková et al., 2015), Study II (Valníčková et al., 2020), Study III (Stěhulová et al., 2017), and one scientific methodology & data article- Data I (Valníčková et al., 2022).

3.1 Study I - The effect of age at separation from the dam and presence of social companions on play behaviour and weight gain in dairy calves

The objective of Study I (Valníčková et al., 2015) was to investigate the independent and combined effects of the presence of the mother during the colostrum-feeding period and subsequent group housing with peers on play behaviour and growth in dairy calves.

Evidence exists that both brief maternal rearing and group housing may have an effect on behaviour in dairy calves. However, it had never been investigated whether an interaction between these two enrichments of the social environment exists. It is possible that if calves are provided with both components of the natural social environment (mother and later housing with peers), their growth potential and welfare status will be particularly positively affected.

We predicted that the growth potential, play behaviour and welfare status in the calves were particularly positively affected, when housed with mothers for the first 4 days after birth and housed in groups with 4 other calves thereafter. Three hypotheses were established based on these predictions.

1. Calves kept with the mother in the colostrum feeding period and then housed in groups will play more in the home environment than the calves kept without the mother in colostrum feeding period and then housed individually.
2. Calves kept without the mother in the colostrum feeding period and then housed individually will play more after being moved to an enriched

environment (“rebound effect“), than the calves kept with the mother during the colostrum feeding period and then housed in groups.

3. Calves kept with the mother in colostrum feeding period and then housed in groups will have higher weight gain than calves kept without the mother during the colostrum feeding period and then housed individually.

3.2 Study II- Early social experiences do not affect first lactation production traits, longevity or locomotion reaction to group change in female dairy cattle

The objective of Study II was to document whether and how social environment during early ontogeny affect first lactation production traits, longevity of a cow or locomotion reaction to group change in female dairy cattle

In contrast to the increasing knowledge about the short-term effects, much less has been researched about long-term effects that would occur months and years after the calves were exposed to the alternative early social environments. While performance of dairy cows at the first lactation is influenced by many factors such as management, feeding, health etc., the influence of early social housing up to 8 weeks of age might also have an effect on the primiparas’ productive life and cows’ reaction to management and husbandry practice in a dairy farm.

The aim of the study was to assess whether the presence of the mother and of the companions during the early ontogeny of female cattle will improve their reproductive and milking performance compared to early separated and individually housed calves. Specifically, we predicted that calves kept with mothers for 4 days and/or in group housing up to 8 weeks will

1. have higher survival rate till first lactation
2. live longer (longevity)
3. have higher milk yield
4. have better milkability (grams of milk ejected per second)
5. have lower post-delivery weight loss

6. have lower activity increase in locomotion after being moved to another group

than calves separated 24h pp from the mothers and/or housed individually.

3.3 Data I- Productional data of primiparous dairy cows reared in different social environments during the first 8 weeks after birth

For purposes of Study II, there was used the data collected by commercial Precision dairy monitoring systems created and produced by company Afimilk Ltd. Precision dairy monitoring systems are not just a useful tool for the farmers, but offer also to be a source of precise and big data useful for scientific purposes. The use of precision monitoring systems created for commercial farming purposes in science is still very new and needs to be validated for scientific use.

Objective of this article was to describe and document new methods of data collection using precision dairy monitoring systems for scientific purpose and provide the access to a metadata obtained by the precision dairy monitoring systems for further studies about the effect of various social environments of calves on their welfare and later production. Since this data article was strictly descriptive and methodological, no hypotheses were tested here.

3.4 Study III- Weaning reactions in beef cattle are adaptively adjusted to the state of the cow and the calf

Objective of Study III was to observe behavioural changes and intensiveness of behavioural signs of stress in cows and calves during separation of calves from their mothers and from mother herd.

In preparation for bringing alternative ways of social housing of dairy calves (i. e. with mothers and subsequently in groups with other calves) into the dairy farming practice, is necessary to investigate properly intensity of reaction to separation from the mother, mother herd and weaning from the milk and test the factors what may affect reaction both, calf and cow. A beef cattle herd was used for this study as a model of cow-calf bond due to the lack of a dairy herd where calves were kept with mothers. Social environment of extensively reared beef cattle might be in agreement with natural social environment of cattle, where calves experience natural social development and therefore they are good animal models to investigate reactions of cows and calves to a mutual separation. Results of this study might provide a theoretical background in bringing cow-calf dairy systems into a practice.

This study investigated how parity and current pregnancy of the cow, and age, weight and gender of calf affected the reaction both, cow and calf to an abrupt weaning and mutual separation during the weaning of 5 to 9 months old calves, within management of a farm with extensively kept beef cattle.

Therefore following hypotheses were tested:

1. Cow reaction to weaning will be stronger if the calf is younger, if the calf is a female, and if the calf had higher daily weight gain
2. Cows in a higher parity and cows that are not concurrently pregnant will react more on weaning
3. Young, female, and calves with higher daily weight gain will respond more to weaning.

4 Published articles

4.1 Study I- The effect of age at separation from the dam and presence of social companions on play behaviour and weight gain in dairy calves (Valníčková et al., 2015)

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The effect of age at separation from the dam and presence of social companions on play behavior and weight gain in dairy calves

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ABSTRACT

Play behavior positively affects welfare of farm animals, yet impoverished social environment during early ontogeny may limit the opportunity or motivation to play. This study investigated the independent and the combined effects of the presence of the dam during the colostrum feeding period and subsequent group housing on play behavior and growth in dairy calves. Forty female calves were allocated to 1 of 4 treatments according to a 2 × 2 factorial design. The treatments were with or without mother during the 4 d after birth and companion housing (single pens or grouped housing in pens of 4 calves between 1 and 8 wk of age). After 8 wk of age all calves were housed in groups of 4 calves. Play behavior of the calves was observed at 2, 5, and 12 wk of age in the following situations: 6 h of spontaneous behavior in the home pen, a 15-min open-field test, and a 15-min social test with an unfamiliar calf. Additionally, play behavior after grouping or relocation at 8 wk of age was recorded during two 2-h sessions. There were no significant effects of the mother by companion interaction either on the amount of play behavior in any of the tests or on the body weights of the calves. Presence of the mother after birth did not increase later playfulness, with the exception of higher spontaneous play at 12 wk of age. When calves were housed in groups of 4, they played more in the home pen on wk 2 and 5 than individually housed calves of the same age. In contrast, individually housed calves were more playful during open-field tests and social tests on wk 2 and 5. At 8 wk, single calves that were placed in a new pen with 3 unfamiliar calves played more than twice as much as grouped calves that were just moved to a new pen with familiar companions. These results show that single-housed calves are deprived of natural levels of play, as demonstrated by both their lower spontaneous play behavior and the higher rebound effect when they are exposed to larger spaces or larger spaces plus companions. Calves that stayed with their mothers for 4 d postpartum grew much better until the end of the second week. After that, grouped calves grew better until wk 10 and they tended to be heavier for at least 2 wk after relocation or mixing at wk 8. The study shows that brief maternal rearing and group housing independently improve different aspects of performance and welfare of dairy calves.
Key words: calf, play behavior, ontogeny, welfare, housing

INTRODUCTION

Under natural conditions, young calves live in a complex social environment. Immediately after birth, the cow is the calf's first social partner. Later on, the calf gradually spends more time associating with peers and other cows (Edwards and Broom, 1982; Le Neindre and Sourd, 1984). In contrast, on most dairy farms young calves are separated from their mothers a few hours after birth and then housed in individual pens until 6 to 8 wk of age. Both the deprivation of maternal care through early separation and the isolation from peers through individual housing may compromise the welfare of the calf. Attempts have been performed to partially restore the natural social environment through postponing the separation from the mother for a few days and housing calves in groups from the second week of life. One approach to measure whether these modifications improve welfare is to record play behavior of the calves. Play behavior may be a good indicator of welfare in young mammals (Held and Špinka, 2011) because its frequency decreases under unfavorable conditions (Bekoff, 1972; Dannemann et al., 1985; Jensen et al., 1998; Špinka et al., 2001; Rushen and de Passillé, 2012). For example, play decreases when the intensity of light is insufficient (Dannemann et al., 1985), when food provisioning drops (Krachun et al., 2010; Duve et al., 2012), or when calves are subjected to painful procedures such as hot-iron disbudding (Mintline et

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al., 2013). Housing calves in group pens with sufficient space allowance has been reported to increase play behavior (Jensen et al., 1998; Jensen and Kyhn, 2000; Duve and Jensen, 2012). Stěhulová et al. (2008) looked at the effect of brief dam-rearing on later calf play behavior and found increased social play in 1 of their 2 dam-rearing treatments.

Both staying with the mother or group housing can also enhance calf BW (Warnick et al., 1977; Flower and Weary, 2001; Tapki, 2007; Babu et al., 2009), although some studies failed to find this effect (Hänninen et al., 2003; Phillips, 2004). Also, it remains unclear for how long the weight advantage of mother-reared or group-housed calves lasts. The effect of maternal presence may be negated very quickly when the calves are separated from the mothers at, for example, 4 d, as the separation may lead to weight loss.

Thus, evidence exists that both brief maternal rearing and group housing may improve welfare and enhance growth in dairy calves. However, it has never been investigated whether an interaction between these 2 enrichments of the social environment exists. It is possible that if calves are provided with both components of the natural social environment, their growth potential and welfare status will be particularly positively affected. Therefore, our study investigated the independent and the combined effects of the presence of the dam during the colostrum-feeding period and subsequent group housing on play behavior and growth in dairy calves.

MATERIALS AND METHODS

Animals and Housing

The observations were carried out at the experimental farm of Institute of Animal Science in Prague (Czech Republic). The calves were kept with their mothers in a straw-bedded calving pen (4 × 3 m) until separation. After separation from mother they were fed 2 L of milk (or colostrum before 5 d of age) twice a day from open buckets until 8 wk of age. Calves had ad libitum access to hay, starter mixture, and water during the entire rearing period.

Experimental Design and Procedures

The study was designed and performed in accordance with European and Czech laws. The protocol was approved by the Institutional Animal Care and Use Committee of the Institute of Animal Science.

In the study, 40 experimental heifer calves (11 Czech Red Spotted and 29 Holstein) were randomly allocated, at the time of their birth, to 1 of 4 treatments according to a 2-factorial design. The first treatment (**MTHR**) differentiated between calves kept with and without their mother during the first 4 d. After the separation from mother until 1 wk of age, all the calves were housed individually to ensure that they knew how to drink milk from an open bucket. Thereafter, the companion treatment (**COMP**) was imposed that distinguished between calves reared with 3 social companions (**GRP**) and calves reared in individual pens (**SNGL**) between 1 and 8 wk of age. The SNGL calves remained in the same particular individual pen from separation until grouping at 8 wk and the GRP calves remained in the same group pen between wk 1 and 8. The individual pen consisted of an individual plastic hut (1.2 × 1.4 m, 1.7 m^2) and an outside run (1 × 1.2 m, 1.2 m^2). The calves in individual pens had visual but not tactile contact with 2 other calves in neighboring pens, as a gap of 40 cm was present between the pens. The group pen consisted of 4 individual plastic huts (4 × 1.7 m^2) connected by the central outside run (4 × 1.2 m^2). All huts had solid floor, richly bedded with straw (4 kg/calf, cleaned and added 3 times per week). The outside run had solid floor that was cleaned once a week. In the GRP treatment, 2 heifer calves and 2 bull calves of similar age were housed together in each of 20 groups, but only 1 heifer per group was followed as the experimental animal. Thus, there were 40 experimental animals, or 10 experimental animals per each treatment combination. Because of the limited herd size, 2 to 3 heifers were entering the experiment in a month according to the current number of calvings at the farm. The order of assignment of calves to the 4 treatments was randomized. The breed of the calves could not be fully randomized across the treatments because we could not influence in which order the calves of the 2 breeds and of the 2 sexes would be born. The COMP treatment was moderately balanced for breed at the beginning of the experiment (Holstein-to-Czech Red Spotted ratio was 16:4 in the SNGL treatment and 13:7 in the COMP treatment) and nearly balanced at 12 wk (14:4 SNGL, 12:4 COMP). However, the MTHR treatment was not balanced in terms of breed either at the start (the breed ratio being 17:3 among calves separated from mother immediately and 12:8 among calves kept with mothers) or at the end of the experiment at 12 wk (the breed ratios being 15:1 and 11:7, respectively). Therefore, we controlled for the effect of breed by including it as a fixed factor in the statistical models. There was no difference in birth weight between calves allocated to the 4 treatments ($F_{3,36} = 0.77$; $P = 0.518$).

At 8 wk of age, calves from the SNGL treatment were grouped with 3 unfamiliar calves (1 heifer and 2 bull calves). Calves in the GRP treatment were moved to a new group pen together. In each of the groups, only 1 heifer was the experimental animal. Calves were kept in these large group pens until 12 wk of age. These pens consisted of a plastic hut (9 m^2, 2.5 m high) and an outside run (9 m^2). All areas had a solid floor, and the hut was heavily bedded with straw (16 kg, cleaned and added 3 times per week). Each pen had 2 pieces, which were filled alternately during the experiment. The calves were weighed with an electronic scale (Eziweigh2, Tru-Test Ltd., Auckland, New Zealand) immediately after birth, at 4 d of age, at 7 d of age, and then weekly until 12 wk of age.

Behavioral Recording in Home Pen at 2, 5, and 12 wk

At 2, 5, and 12 wk of age, the undisturbed behavior of calves was video recorded in the home pen without any manipulation. A video camera connected to a video recorder was positioned 2.5 m above floor level in front of each pen. Based on a preliminary examination of diurnal distribution of the play activity of calves, the interval between 1300 and 1900 h was used for analysis of play behavior, as this was the 6-h interval in which play behavior was most frequent. Group-housed calves were marked by experimental commercial animal spray colors approximately 1 h before the video recording started.

Behavioral Recording After Mixing or Movement into a New Pen at 8 wk

At 8 wk of age, calves were moved to large group pens. The 3 pen mates were always moved to the group pen 15 min before the experimental animal, and the video recording started immediately after the experimental animal was placed in the pen (at approximately 0900 h). Calf behavior was recorded for 4 h after it was released to the pen and for 4 h on the next day. The interval between 0900 and 1100 h each day was used for analysis of play behavior, because in the preliminary study it was during this interval calves were most active.

Open-Field Test and Test with Unfamiliar Calf at 2, 5, and 12 wk

The calves were tested in an open field at 2, 5, and 12 wk of age on the day after the observations in the home pen. The test was performed in a separate straw-bedded pen (2 × 4 m). The calves were moved individually to the pen and video-recording started immediately after the door was closed. After 15 min, an unfamiliar calf was brought into the pen. The test lasted 30 min (15 min of isolation and 15 min with an unfamiliar calf). Play behavior of experimental calves during the whole 30 min of the test was analyzed from video tapes. The described test was similar to, but not identical with, previous tests designed to assess rebounds of locomotor play behavior and responses to unfamiliar conspecifics (e.g., Duve and Jensen, 2011; Mintline et al., 2012; Rushen and de Passillé, 2014).

Video Analysis and Statistical Evaluation

The play behavior of the calves was analyzed from video tapes using one-zero sampling (Martin and Bateson, 2007) at 1-min intervals. Behaviors listed in Table 1 were identified as play. The definitions of play were partly inspired by previous studies (e.g., Jensen et al., 1998). Two broad categories of play were distinguished. Individual play included locomotor-rotational and object play that did not include physical contact between 2 calves, whereas social play included contact play behavior and locomotor-rotational play performed in close coordination between 2 or more calves. When any of the play behaviors occurred during the given minute, the minute was labeled as play occurrence. For each recording session, the number of minutes with play occurrence per hour was calculated and used as dependent variable. If necessary, the variables were log-transformed to assume normality.

To avoid pseudoreplication in GRP treatment, only 1 experimental heifer calf from each of the 20 groups was included in the analysis. Due to the death of 2 calves and failures in management and video recording, the actual number of calves that contributed valid data ranged between 29 and 34 for different tests. For any statistical test, data from at least 7 calves were available for each of the 4 MTHR × COMP treatment combinations. Data were analyzed using SAS version 9.4 (SAS Institute Inc., Cary, NC). For behavioral data from wk 2 and 5, linear mixed models (proc mixed in SAS) were applied, with week of testing, the 2 treatments (MTHR and COMP), and the MTHR × COMP interaction as fixed factors. Three linear mixed models with play minutes per hour as a dependent variable were calculated, the first for the two 6-h recordings in the home pen at 2 and 5 wk of age, the second for the 15-min open field tests, and the third for the 15-min test with unfamiliar calf at 2 and 5 wk of age. A fourth analysis using a linear mixed model was run with proportion of social play as a dependent variable for the home pen data of the GRP calves. Calf identity was included as a random factor in all these models, thus taking care of the fact that the same variables were recorded on each calf twice at 2 and at 5 wk. The

Table 1. Ethogram of play behavior based on studies Jensen et al. (1998) and Stěhulová et al. (2008)

Type of play	Description
Individual play	
Solitary locomotor-rotational play	
Run	Galloping movement, only 1 calf in a group is running at the moment
Leap	Leaving the ground without horizontal movement
Jump	Moving any horizontal distance while off the ground
Rear	Rocking backward into a bipedal position and then falling or jumping forward
Head jerk	Rapid move head from side to side or from bottom to top
Head shake	Shaking head from side to side or rotating head
Buck-kick	Hind legs rapidly kick up and back
Fast turn	Rapid direction change while running
Fast stop	Abrupt halt while running
Turn	Rapid direction change, rotation around vertical axis
Object play	Butting buckets, straw or other inanimate objects in the pen
Social play	
Contact play	
Butt	Frontal pushing and butt head to head or head to body contact
Mount	Fore legs are on the back of another calf (mock sexual behavior)
Kick	Striking another animal with one or both hind limbs
Coordinated locomotor play	
Run together	Galloping movement closely followed by a response of another calf; at least 2 calves are running simultaneously in the same direction
Leap or jump together	Each leap or jump is closely followed by a response of another calf

analyses of behavioral data from wk 8 and 12 were accomplished using general linear models with MTHR, COMP, and the MTHR × COMP interaction as fixed factors. Five separate general linear models were run, namely for the first day after mixing in wk 8, for the second day after mixing at wk 8, for the 6-h recordings in the home pen at wk 12, for the 15-min open field tests at wk 12, and for the 15-min test with an unfamiliar calf at wk 12. Calf breed was also included as a fixed factor and the calf's current weight as a covariate in all mixed and general linear models.

RESULTS

Interaction Between the MTHR and COMP Effects

There were no significant effects of the MTHR × COMP interaction either on the amount of play behavior in any of the tests or on the BW of the calves (all $P > 0.1$).

Effects of 4 d with Mother on Later Play

Calves kept with their mothers for 4 d postpartum played more in the home pen on wk 12 than calves separated from mothers immediately (Figure 1, Table 2). On wk 2 and 5, the effect of mother rearing on play was not significant (Table 2). Age at separation from the mother had no significant effect on the amount of play after grouping or relocation at wk 8 (Table 2), in the open-field tests at wk 2, 5, and 12 (Table 2), or during the tests with unfamiliar calf at wk 2, 5, and 12 (Table 2).

Effects of Group Housing on Later Play

Group-housed calves tended to play significantly more in the home pen than individually housed calves at wk 2 and 5 (Figure 2, Table 2). At 12 wk, no significant difference in the frequency of play in the home pen could be detected between calves that had been housed in groups or individually housed up to wk 8 (Table 2).

Immediately after the grouping or relocation at 8 wk, SNGL calves played more than GRP calves (Figure 3, Table 2), and they still played marginally more 24 h later (Table 2). On wk 2 and 5, SNGL calves played more during the 15-min open-field test than GRP calves (Figure 4, Table 2) and played more during the test with an unfamiliar calf (Figure 5, Table 2). On wk 12, no effects of the previous SNGL versus GRP treatments were present on play in open field (Figure 4, Table 2) or play in the presence of an unfamiliar calf (Figure 5, Table 2).

Effects of BW on Play

The current individual BW did not influence play behavior in either the home pen, during the mixing, in the open field, or in the tests with unfamiliar calf on any of the weeks (all $P > 0.1$). The only exception was that play behavior during on the first day of mixing at wk 8 tended to be positively affected by BW ($F_{1,31} = 3.51$; $P = 0.071$).

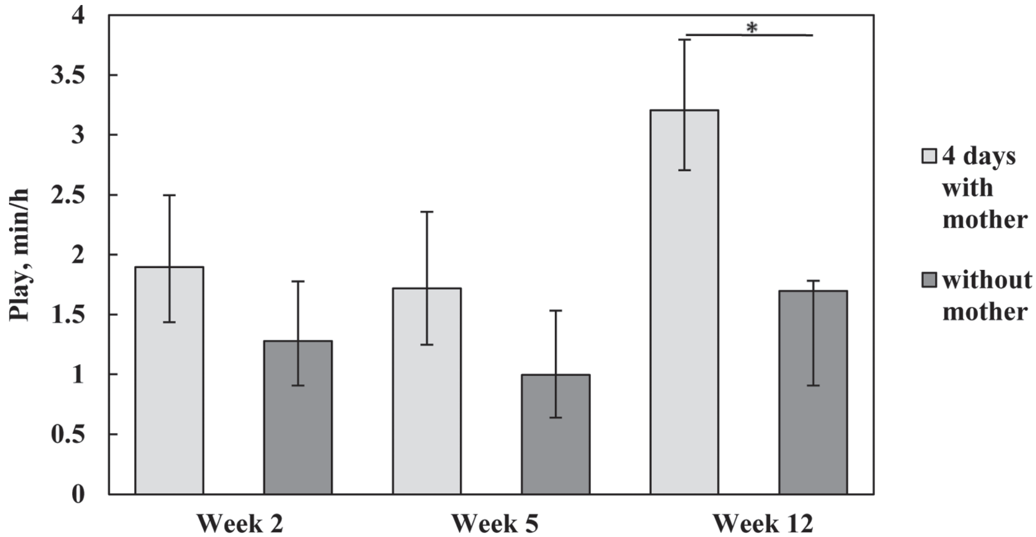

Figure 1. The effect of separation from mother on d 1 or 4 on play levels in the home pen on wk 2, 5, and 12 (geometric LSM ± SE). An asterisk (*) represents $P < 0.05$.

Development of the Proportion of Social Play

The proportion of social play expressed by the GRP calves in the home pen was not affected by the age at separation from the mother (Table 2). The proportion of social play increased with age in the home pen (Table 2) from 0.22 ± 0.06 at wk 2 to 0.33 ± 0.06 at wk 5 and 0.60 ± 0.06 at wk 12.

Effect of 4 d with Mother and Group Housing on Weight of Calves

At d 4, calves housed with mothers were heavier than calves separated immediately after birth from mothers (49.2 ± 1.2 vs. 43.8 ± 1.7 kg; $F_{1,27} = 8.09$; $P = 0.008$). The difference persisted as significant until wk 1 (48.0 ± 1.2 vs. 44.1 ± 1.3 kg; $F_{1,34} = 5.28$; $P = 0.028$). Starting with wk 2, the differences in BW between the calves separated from their dam at d 1 and 4 were not significant.

Figure 6 shows that group-housed calves grew better than single-housed calves and achieved significantly higher weights on wk 4 ($F_{1,34} = 6.65$; $P = 0.014$). The GRP calves continued to be heavier throughout the period of differential housing (wk 5: $F_{1,33} = 11.19$, $P = 0.002$; wk 6: $F_{1,33} = 15.25$, $P < 0.001$; wk 7: $F_{1,32} = 17.08$, $P < 0.001$; wk 8: $F_{1,33} = 10.40$, $P = 0.003$). Heavier BW persisted in the previously GRP calves for at least 2 wk after the differential housing ceased on wk 8 (wk 9: $F_{1,32} = 8.18$, $P = 0.007$; wk 10: $F_{1,3} = 4.56$, $P = 0.041$).

Effect of Breed on Play and Weight of Calves

The breed of the calf had no effect on any of the play behavior or BW variables (all $P > 0.1$), with 2 exceptions. In the open field tests on wk 2 and 5, a tendency was noted for the Holstein calves to play more than the Czech Red Spotted calves ($F_{1,24} = 3.77$; $P = 0.064$), and at wk 11 the Holstein calves weighed more than the Czech Red Spotted calves ($F_{1,30} = 4.60$; $P = 0.040$).

DISCUSSION

Interaction Between Maternal Rearing and Group Housing

No interaction effects were observed between keeping calves with the mother for 4 d and later group housing on either play or BW. Thus, it does not seem that the 2 aspects of more natural social rearing environment improve welfare or performance in a multiplicative way. However, it should be noted that the 2 treatments did not overlap in time, as the MTHR treatment was applied only for the first 4 d and the COMP treatment did not start before d 7. It is possible that if calves were left with the mother for longer period of time that overlapped with grouping with other calves, a synergistic effect on social behaviors, such as play, could be present.

Effects of Age at Separation

We found some indication that the presence of mother after birth may increase later playfulness, as higher

Table 2. Results of the statistical analysis of play behavior[1]

Time	Response variable or situation	Statistical test	Effect	df	*F*-value	*P*-value
wk 2 and 5	Play in home pen	Mixed linear model	MTHR	1,32	1.45	0.238
wk 12	Play in home pen	General linear model	MTHR (4 d with mother > separated immediately)	1,27	5.46	0.027
wk 8, d 1	Play after grouping or relocation	General linear model	MTHR	1,31	0.40	0.523
wk 8, d 2	Play after grouping or relocation	General linear model	MTHR	1,31	0.43	0.529
wk 2 and 5	Play during open field test	Mixed linear model	MTHR	1,24	1.40	0.248
wk 12	Play during open field test	General linear model	MTHR	1,27	0.61	0.442
wk 2 and 5	Play during test with unfamiliar calf	Mixed linear model	MTHR	1,25	0.07	0.797
wk 12	Play during test with unfamiliar calf	General linear model	MTHR	1,26	0.01	0.935
wk 2 and 5	Play in home pen	Mixed linear model	COMP (GRP > SNGL)	1,32	3.49	0.071
wk 12	Play in home pen	General linear model	COMP	1,28	0.07	0.796
wk 8, d 1	Play after grouping or relocation	General linear model	COMP (SNGL > GRP)	1,31	21.63	<0.001
wk 8, d 2	Play after grouping or relocation	General linear model	COMP	1,31	3.33	0.078
wk 2 and 5	Play during open field test	Mixed linear model	COMP (SNGL > GRP)	1,24	5.35	0.030
wk 12	Play during open field test	General linear model	COMP	1,27	0.01	0.923
wk 2 and 5	Play during test with unfamiliar calf	Mixed linear model	COMP (SNGL > GRP)	1,25	20.09	<0.001
wk 12	Play during test with unfamiliar rcalf	General linear model	COMP	1,26	0.12	0.737
wk 2, 5 and 12	Proportion of social play in home pen	Mixed linear model	MTHR	1,27	0.12	0.734
wk 2, 5 and 12	Proportion of social play in home pen	Mixed linear model	WEEK (wk 2 < wk 5 < wk 12)	1,27	15.36	<0.001

[1]The treatment MTHR differentiated between calves kept with and without their mother during the first 4 d. The COMP treatment distinguished between calves reared with 3 social companions (GRP) and calves reared in individual pens (SNGL).

spontaneous play was recorded at 12 wk of age in calves that stayed with mothers for the first 4 postpartum days. However, this evidence is weak, as other findings of the current study do not support it. The mother's presence during the first 4 d of life did not affect levels of calf playfulness either in the home pen at 2 and 5 wk or during testing procedures similar to routine farm husbandry (i.e., transfer of calves between pens and mixing with new companions after weaning from milk, short isolation during open-field test, and an encounter with an unfamiliar calf). Similarly ambiguous evidence for effects of early maternal presence was found in the study of Stěhulová et al. (2008), where social play at 3 wk of age was higher in calves separated from mothers at 4 d than in calves separated either at 1 or 7 d and individual play was unaffected. Taken together, the 2 studies indicate that brief postnatal presence of the dam does not substantially increase later playfulness in dairy calves. It remains an open question whether a longer postnatal cohabitation with the mother would have a stronger influence on later calf playfulness. Even when the play behavior of calves remaining with their mothers and calves separated immediately after birth were compared at 90 d, the differences were complex, with the mother-reared calves displaying more social play but less locomotor play (Wagner et al., 2013).

It is possible that the effect on play of staying with the mother for a few days is modified by subsequent rearing conditions. In our study, as well as in the study of Stěhulová et al. (2008) on a Swedish farm, calves were fed only 4 L of milk a day after separation, meaning that following separation the calves' feeding level probably halved. Such a sudden drop in milk intake may negate the potential long-term positive effects of mother-rearing.

In our study, we mainly focused on the total quantity of play. A detailed analysis of social as opposed to individual play was precluded by the fact that social play

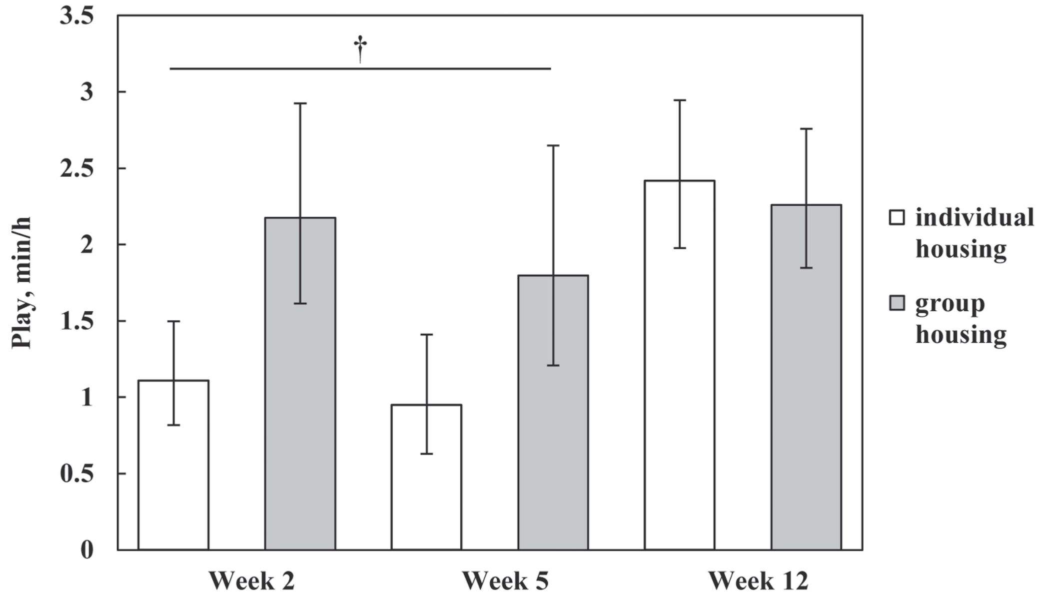

Figure 2. The effect of individual versus group housing on play levels in the home pen on wk 2, 5, and 12 (geometric LSM ± SE). A cross (†) represents $P < 0.1$ for the housing effect on wk 2 and 5.

was impossible in individually housed calves. Nevertheless, we analyzed the proportion of playful minutes that were devoted to social play behavior in the home pen for the GRP calves. We found no evidence that the age at separation affected later proportion of social play. However, the proportion of social play increased with age in our study, indicating that the quality of play will be a valuable parameter for further studies.

Effects of Companions

When calves were housed in groups of 4, they played more than their individually housed age mates. In agreement with other studies (Jensen et al., 1998; Babu et al., 2004; Tapki et al., 2006), the results indicate that the most common housing system for dairy calves, the small individual pen, reduces the natural expression of

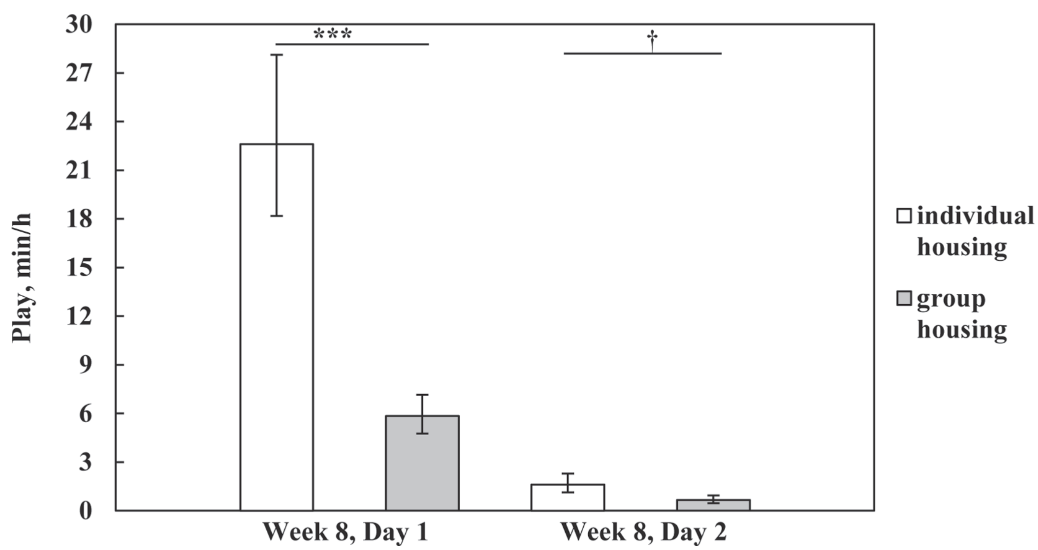

Figure 3. The effect of individual versus group housing on play levels after being moved to a new pen on wk 8 (geometric LSM ± SE). Three asterisks (***) represents $P < 0.001$, a cross (†) represents $P < 0.1$.

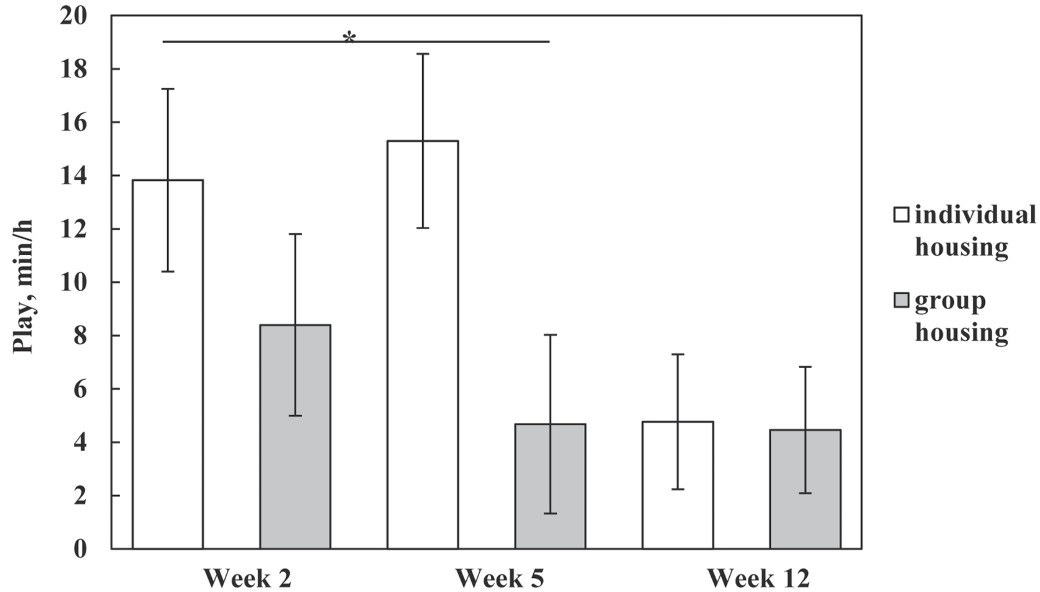

Figure 4. The effect of individual versus group housing on play levels in the open field test on wk 2, 5, and 12 (LSM ± SE). An asterisk (*) represents $P < 0.05$ for the housing effect on wk 2 and 5.

play behavior. This could be either due to the absence of companions, or due to the lack of space available. The studies published so far show that space availability plays the major role (Jensen et al., 1998; Jensen and Kyhn, 2000; Tapki et al., 2006; Mintline et al., 2013). Pens ranging between 1.3 to 5.4 m^2 for single calves and between 5.4 to 16.2 m^2 for groups of 3 to 4 have been tested in the current and previously cited studies with increases in play behavior reported along the scale. The presence of at least 1 companion in the home pen may also enhance play when play is inhibited by limited milk allowance (see Jensen et al., 1998; Duve et al., 2012), but when a higher amount of milk is fed (>5 L per day) social companions do not seem to increase play

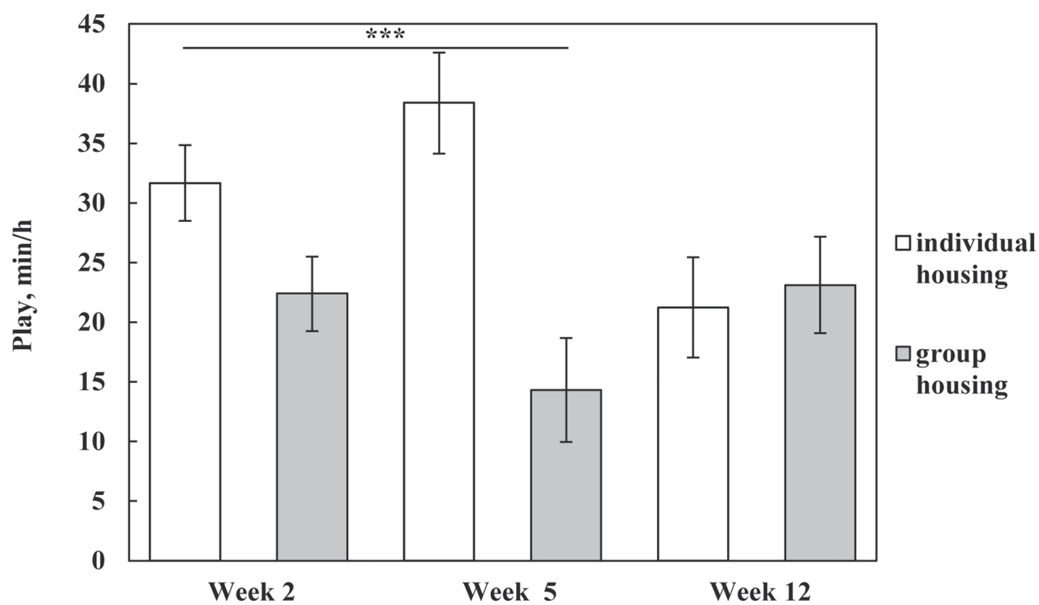

Figure 5. The effect of individual versus group housing on play levels in the test with unfamiliar calf on wk 2, 5, and 12 (LSM ± SE). Three asterisks (***) represents $P < 0.001$ for the housing effect on wk 2 and 5.

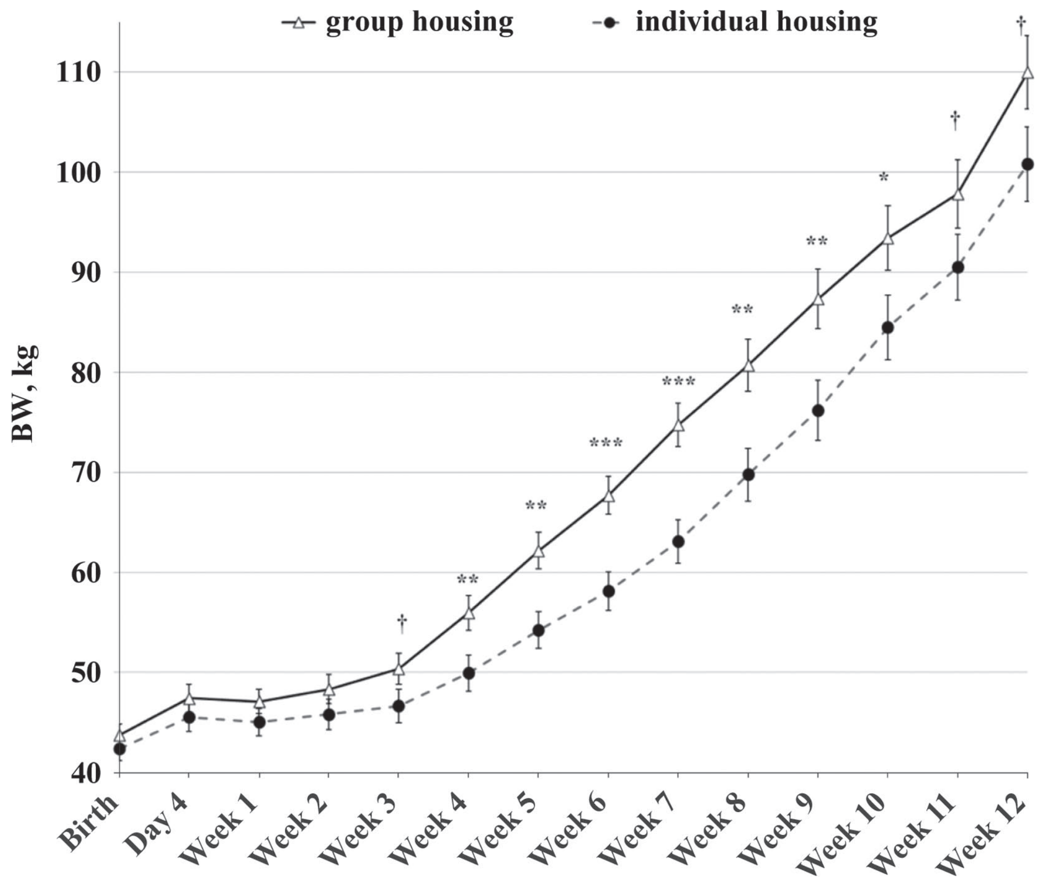

Figure 6. The effect of individual versus group housing on BW (LSM ± SE). Three asterisks (***) represents $P < 0.001$, two asterisks (**) represents $P < 0.01$, one asterisk (*) represents $P < 0.05$, and a cross (†) represents $P < 0.1$.

levels (Duve et al., 2012; Jensen at al., 2015). Other factors may undoubtedly also enhance play levels, such as feeding higher amount of milk (Krachun et al., 2010; Duve et al., 2012; Jensen et al., 2015) or provision of fresh straw.

In the 15-min open-field test at 2 and 5 wk, SNGL calves played 3 to 4 times more than the calves from the GRP housing. Also, during the 15-min encounter with an unfamiliar calf, play levels of SNGL calves surpassed GRP calves. At 8 wk, SNGL calves that were placed in a new pen with 3 unfamiliar calves played more than twice as much as GRP calves, who were just moved to a new pen with their companions. Higher level of play in the formerly single-housed calves even persisted until the next day. These differences demonstrate a powerful rebound effect (Dawkins, 1988) in play behavior when calves housed in individual pens are exposed to larger space and companions. These results agree with previous studies that also demonstrated a higher frequency of play during open-field tests when calves and heifers were previously isolated or confined (Jensen, 1999; Jensen et al., 1999; Jensen and Kyhn, 2000; Duve and Jensen, 2011; Rushen and de Passillé, 2014). More specifically, Jensen (2001) demonstrated that the motivation to perform locomotor play and trotting increases with length of confinement. The increase in play activity can be explained in 2 ways (Mintline et al., 2012). It may be due to a buildup of inner motivation to play during deprivation, or it may be a response to novelty (i.e., the first contact with a social partner and with a new pen). The fact that in the home pens, play activity of SNGL calves was lower indicates that they might have been play-deprived. Also, the persistence of higher play levels in SNGL calves for at least 24 h after the encounter of new partners at 8 wk indicates that novelty alone does not explain the observed differences. In a study that specifically addressed the role of motivational factors in calf rebound play, Rushen and de Passillé (2014) also concluded that the play levels in this situation are unrelated to exploration and hence to novelty effects.

Effect of 4 d with Mother and Group Housing on Weight of Calves

Calves that stayed with their mothers for 4 d postpartum grew much faster during this first period and they were still heavier at the end of the first week, but the difference disappeared by wk 2. It is well documented that calves allowed to stay with their dams grow much faster (Krohn et al. 1999; Flower and Weary 2001). This effect is probably due to higher milk consumption, especially if the separated calves are fed a low milk allowance, as was the case is our study. Nevertheless, enhanced growth was observed even in calves housed with their mothers yet prevented from suckling (Krohn et al., 1999). For how long the weight advantage lasts after separation is not clear. Whereas Krohn et al. (1999) and Stěhulová et al. (2008) found no difference in weight 2 wk after the housing treatment ended, in our study the advantage maintained for a week and in Flower and Weary (2001) it lasted for at least 2 wk. The postseparation growth undoubtedly depends on the amount of milk fed to calves. In the study of Flower and Weary (2001), calves were fed 10% of BW in milk, which might have promoted the persistence of weight advantage of previously suckled calves, whereas the other 2 studies provided 4 L of milk to all calves, probably undercutting the growth potential of the previously suckled calves. Feeding 4 L of milk a day, although still practiced on many farms, is now considered too low a provision (Sweeney et al., 2010). It is possible that the effect of age of separation on calf growth would be different if, for instance, 8 L was provided to the calves after separation.

The GRP calves were placed into group pens on wk 1 and this promoted their BW gains such that, at the end of differential housing at wk 8, they weighed about 10 kg or 15% more than SNGL calves. It is unclear what mechanism could be behind the higher weight gain of the grouped calves in our study. The GRP and SNGL calves were fed the same, albeit low, amount of milk. Also, it is improbable that faster growth was due to lower energy expenditure for physical activity because GRP calves actually played more than SNGL calves and higher play levels are indicative of higher total locomotion (Rushen and de Passillé, 2012). In 3 previous studies, grouped (Phillips, 2004; Hepola et al., 2006) and paired (De Paula Vieira et al., 2010; Jensen et al., 2015) calves, respectively, were consuming more solid food than individually housed calves, although Chua et al. (2002) did not find the same effect in an earlier study. Possibly, social facilitation (Zajonc, 1965) or social learning (De Paula Vieira et al., 2012; Gaillard et al., 2014) may increase solid food intake in grouped calves, as has been reported in dairy cows (Grant and Albright, 2000), chicken (Keeling and Hurnik, 1996), and humans (de Castro, 1994).

Some previous studies also found higher weight gain in grouped calves (Warnick et al., 1977; Babu et al., 2004; Babu et al., 2009), but others did not (Broom and Leaver, 1978; Purcell and Arave, 1991; Hänninen et al., 2003; Phillips, 2004). Most published studies on paired calves did not show a weight advantage over single-housed calves (Chua et al., 2002; De Paula Vieira et al., 2010; Duve and Jensen, 2012). This mixed picture may be due to various methodological differences between the studies, especially the widely different milk allowance that ranged from 3 to 4 L (Purcell and Arave, 1991; Babu et al., 2004), through 6 L (Hänninen et al., 2003; Duve and Jensen, 2012), up to ad libitum feeding (Chua et al., 2002; De Paula Vieira et al., 2010). Jensen et al. (2015) recently investigated the interaction between pair housing and milk allowance. They found that pair housing increased weight gain in calves fed 9 L per day (possibly due to higher grain intake), but not in calves fed 5 L per day. Also, the failure of some of the studies to find significant differences may be due to small sample sizes in relation to the large interindividual variability. We checked 12 studies that provided the average BW of the grouped or paired versus individually housed calves (Warnick et al., 1977; Broom and Leaver, 1978; Purcell and Arave, 1991; Chua et al., 2002; Hänninen et al., 2003; Babu et al., 2004; Phillips, 2004; Babu et al., 2009; De Paula Vieira et al., 2010; Duve and Jensen, 2012; Jensen et al., 2015). In 11 of the 12 studies (all except Phillips, 2004), the overall average BW of grouped or paired calves were higher numerically. It would be worthwhile to perform a meta-analysis over all the available data set to see whether the weight advantage of group-housed calves is a general phenomenon.

The improvement in weight gain due to group housing may be transient, as we could statistically prove higher BW for only 2 wk after the differential social situation had ended. However, the effect might also last longer, as indicated by the marginally significant difference at wk 12. Only a study including a larger sample size could confirm whether the weight advantage is short-lived or lasts longer.

CONCLUSIONS

Housing calves in groups of 4 between wk 1 and 8 increased play rates and enhanced BW compared with calves housed singly. The BW advantage persisted for several weeks after the differential housing ended. This study adds fresh evidence to support the welfare and performance advantages of group housing calves. When exposed to a larger pen or a companion, the single-housed calves rebounded into intensive play behavior, indicating that they were play deprived in the single pens. Staying with mother for the first 4 d gave calves a weight gain advantage that persisted until beginning of wk 2 but did not increase later play behavior, except for a questionable increase at wk 12. This study shows that brief maternal rearing and group housing independently improve performance and welfare of dairy calves.

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4.2 Study II- Early social experiences do not affect first lactation production traits, longevity or locomotion reaction to group change in female dairy cattle (Valníčková et al., 2020)

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Early social experiences do not affect first lactation production traits, longevity or locomotion reaction to group change in female dairy cattle

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Milk yield

ABSTRACT

Under natural conditions cows and their calves live together. In dairy practice, calves are separated from their mothers within hours after birth and then housed individually. This study investigated the effects of the presence of the dam during the colostrum feeding period and subsequent group housing during early ontogeny on reproduction, milk performance and locomotion at first lactation as well as on longevity in female dairy cattle. Forty female calves were allocated to 1 of 4 treatments according to a 2 × 2 factorial design. The treatments were with or without mother during the 4 days after birth and either single housing or housing in groups of 4 calves between 1 and 8 weeks of age. Thereafter all calves were managed according to routines of the farm until they became primiparous lactating cows. Data about locomotion, milk yield, milking duration and body weight were collected every milking. Information about calving, inseminations, pregnancy and departure of the animal from the herd/group were added to records. We predicted that females raised with early mother contact and group housing will have higher performance as dairy cows. None of the seven performance variables was affected by either the age of separation from the dam or by the type of housing 8 weeks of life. The results indicate that neither provision of maternal care for a few days nor group housing for the duration of milk feeding bring any advantage or disadvantage for later performance in female dairy cattle.

1. Introduction

Under natural conditions, cattle are social animals, living in maternal herds of cows and their calves of both genders (Lazo, 1994). In dairy practice, however, calves are usually separated from their dams within hours after birth and then housed individually for several weeks (Marcé et al., 2010; Staněk et al., 2014). There is a consensus that social deprivation is detrimental to animal welfare (Dawkins, 1988; Latham and Mason, 2008; Rault, 2012; Costa et al., 2016; Cantor et al., 2019). Therefore, farmers and researchers are investigating possibilities how to change this practice, either through raising calves with their mothers for a few days or even weeks (Johnsen et al., 2016), or through keeping the calves, after separation from the mother, in groups (or at least in pairs) instead of individually during the milk-feeding period (Costa et al., 2016; Cantor et al., 2019). Various short term effects (occurring within days or weeks) of both these rearing methods have been examined. As the prolonged stay of the calf with its dam, both positive and negative short-term effects were found. As long as the calves were with their mothers, they grew faster than early-separated calves (Valníčková et al., 2015) and their social behaviour was positively affected for weeks to come (Flower and Weary, 2001). On the other hand, the later separation causes more intense stress reactions in both, the mother (Weary and Chua, 2000; Flower and Weary, 2001; Stěhulová et al., 2008) and the calf (Flower and Weary, 2001). As for the group housing of young calves, positive effects have been demonstrated on health (Hänninen et al., 2003; Babu et al., 2009), weight gain (Babu et al., 2009; Valníčková et al., 2015), development of play (Jensen et al., 1998), social and locomotor behaviour (Jensen, 1999; Jensen et al., 1999; Chua et al., 2002) and emotional state (Bučková et al., 2019). In contrast to the increasing knowledge about the short term effects, much less is known about long-term effects that would occur months and years after the calves were exposed to the alternative early social environments. While performance of dairy cows at the first lactation is influenced by many factors such as management, feeding, health etc., the influence of early social housing up to 8 weeks of age might also have effect on the primiparas' productive life. According to the study of (Brouček et al., 2006), heifers which spent the first week of their life with mother or heifers kept in groups with a foster cow till

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weaning at 8 weeks had better milk production at the first lactation (Brouček et al., 2006). This may be connected with higher food intake during this period, which has a positive effect on the production at the first lactation (Wiedemann et al., 2015). Effects of group housing with other calves on later life and lactation performance have not been investigated by any study yet (Costa et al., 2016; Cantor et al., 2019). Thus, more information about the effects of early social environment on later performance is needed, especially for female cattle that are the replacement stock in the turnover of a dairy herd.

Therefore the aim of our study was to assess whether presence of the mother and of the companions during early ontogeny of female cattle will improve their reproductive and milking performance compared to early separated and individually housed calves. Specifically, we predicted that calves kept with mothers for 4 days and/or in group housing up to 8 weeks will have higher survival till first lactation, longer longevity, higher milk yield, better milkability (average milk ejected per second), lower post-delivery weight loss and lower activity increase in locomotion after being moved to another group than the calves housed without mother or housed individually.

2. Materials and methods

2.1. Animals and experimental procedures

The study was designed and performed in accordance with European and Czech laws. The protocol was approved by the Institutional Animal Care and Use Committee of the Institute of Animal Science.

The observations were carried out at the experimental farm of the Institute of Animal Science in Prague, Czech Republic. In the study, 40 female calves of two breeds (11 Czech Fleckvieh and 29 Holstein) were used, corresponding to the composition of the experimental herd. Data about experimental animals were collected from their birth until their death and exit from the herd.

In the beginning of the experiment, the calves were kept with their mothers in a straw bedded calving pen (4 × 3 m) until separation at either 4 days (20 calves) or 0 days (20 calves). After separation from the mother until 1 wk of age all calves were housed individually and then either individually (20 calves) or in groups of 4 calves (20 calves in 20 groups, with the 3 companion calves in each group not being recorded for the purpose of this study). The calves were randomly assigned into the 4 treatments in a crossed two-factorial design with each treatment being imposed on 10 calves.

The individual pen consisted of an individual plastic hut (1.2 × 1.4 m) and an outside run (1 × 1.2 m). The calves in individual pens had visual but not tactile contact with 2 other calves in neighbouring pens as there was a gap of 40 cm between the pens. The group pen for four calves consisted of 4 individual plastic huts (4 × 1.7 m^2) connected by the central outside run (4 × 1.2 m^2). All huts had solid floor, richly bedded with straw (4 kg per calf, 3 times a week). The outside run had solid floor that was cleaned once a week.

After separation from mother, calves were fed 2 L of milk (or colostrum before 5 days of age) twice a day from open buckets until 8 weeks of age. Calves had ad libitum access to hay, starter mixture and water during the entire rearing period.

At 8 weeks of age, all calves were moved to larger group pens containing 4 calves. Calves were kept in large group pens until 12 weeks of age. These pens consisted of a plastic hut (9 m^2, 2.5 m high) and an outside run (9 m^2). All areas had a solid floor, and the hut was heavily bedded with straw. For more information about the early social housing see (Valníčková et al., 2015). Starting at 12 weeks of age, all experimental animals became part of the production herd and they were submitted to the routine farm management together with all other female cattle on the farm. After 12 weeks of age calves were moved to groups of 24 heifers where they were later inseminated and stayed there until late gestation of their first pregnancy. Age of insemination was dependent on individual weight and body condition. All experimental animals were inseminated between 13 and 18 months of age. Two months before first delivery the heifers were moved to the group with dry cows where they stayed until delivery. Animals in these groups were housed freely on solid concrete floor without bedding and with cubicles (1 cubicle per animal) bedded with straw provided for lying. Heifers had access to an outside run with solid concrete floor. Heifers in groups were fed once a day with a Total mixed ratio (TMR) based on corn silage, haylage and straw. Dry cows were fed once a day with TMR based on haylage, straw and mineral additives. TMR was pushed back to the feeding table 4 times a day in both, heifers and dry cows.

Just before calving pregnant heifers were isolated and placed in a straw bedded calving pen. Within 24 h after delivery the primiparous cows were moved to the group of about 50 high producing cows. After peak of lactation, when their milk yield dropped under 24 kg milk/ day, cows were transferred to the next lactating group of about 48 cows. When their milk yield dropped further, the cows were moved to the last lactating group consisting of approximately 60 cows. Animals in all lactation groups were housed freely and all these groups had solid floor without bedding and cubicles bedded with straw. Cows in all groups had access to outside run with solid concrete floor and cubicles bedded with straw placed under the roof. Manure from group pens was removed two times per day and straw in cubicles was changed once a week. Cows in all lactating groups were fed twice a day with TMR based on corn silage, haylage and straw with mineral and vitamin additives. TMR was pushed back to the feeding table 9 times a day. Lactating cows were milked twice a day at 4am and 4 pm in a tandem parlour with 3 × 3 stalls.

2.2. Data collection

Data about milking, body weight and locomotion were automatically collected and processed by dairy management systems AfiMilk MPC milk meter (milk production monitoring), AfiAct (locomotion e = daily number of steps) and AfiWeight (weight monitoring) created and produced by company Afimilk Ltd. Data about locomotion were collected by pedometers placed on left hind legs of all cows and were automatically scanned during every milking. Data about milk yield and milking duration were collected every milking by sensors placed in the milking stalls. After each milking cows were weighed authomatically. All cows were identified by neck collars and data about locomotion, milking and weight were sent with ID number of each cow to the central computer and processed and stored by dairy farm management software AfiFarm™. Information about calving, inseminations, pregnancy and departure of the animal from the herd/group were added to the software manually by the manager of the farm.

For testing our predictions we selected seven dependent variables based on farm records downloaded from dairy farm management software AfiFarm™; SURVIVAL (survival till the first lactation), LONGEVITY (overall longevity of the cow in the herd), AGEPREGN (age at insemination which led to first pregnancy), MILK (milk yield), MPERSEC (average grams of milk ejected per second), WLOSS (weight loss after parturition), LOCOMOTION (number of steps one day before and one day after group change). For definitions of the variables see the Table 1.

2.3. Statistical evaluation

All data were analysed using SAS 9.4 (SAS Institute Inc., Cary, NC). For testing the hypothesis about SURVIVAL, logistic regression model (proc genmod in SAS, distribution = binomial, link function = logit) was used. Hypotheses about LONGEVITY, AGEPREGN, MILK, MPERSEC, WLOSS were tested through general linear models (proc glm in SAS). All models had three fixed factors – MOTHER (Day 0 vs. Day 4), COMPANION (single vs. grouped) and BREED (Holstein vs. Czech Fleckvieh). The hypothesis about LOCOMOTION was tested using a mixed linear model with four fixed factors (MOTHER, COMPANION,

Table 1
Definitions of tested dependent variables.

Abbreviation of the variable	Name of the variable	Definition of the variable (except for LONGEVITY, all variables relate to the 1st lactation)
SURVIVAL	Survival till the first lactation	Did the heifer survive until the start of the first lactation? (YES /NO). YES = the heifer started her first lactation in the herd; NO = the heifer died or was culled before first calving
LONGEVITY	Overall longevity of the cow in the herd	Age in days that the cow was alive in the herd (birth to exit from the herd). This was the only variable recorded beyond first lactation.
AGEPREGN	Time of insemination which led to pregnancy	Age in days when heifer was successfully inseminated (and later confirmed as pregnant).
MILK	Milk yield	Total milk yield in kilograms for standardized lactation (305 days).
MPERSEC	AVG time for milking	Average grams of milk ejected per second, measured on both milkings on a day (during standardized lactation – 305 days).
WLOSS	Weight loss after parturition	The percentage (1 st day of lactation = 100%) of weight loss on the 21 st day of first lactation.
LOCOMOTION	Behaviour around group change	Average number of steps (measured by pedometers) per hour one day before and one day after the animal was moved between cow groups.

BREED and DAY (before vs. after group change) and two random factors (animal identity and particular group change identity). The normality of dependent variable was checked as the normality of residuals. Missing data were not fitted.

Out of the 40 experimental calves, five died and another five were culled (due to problems in growth, reproduction, health or behaviour) between the end of the treatments at week 8 and first calving. Further two animals were removed from the lactating group at 8 and 20 days post partum due to the need of individual care. Thus, 28 animals were available for the analyses of LONGEVITY, AGEPREGN, MILK, MPERSEC, WLOSS and LOCOMOTION.

3. Results

In contradiction to the main hypothesis of the study, none of the six performance variables (SURVIVAL, LONGEVITY, AGEPREGN, MILK, MPERSEC, WLOSS) was affected by either the age of separation from the dam (0 or 4 days) or by the type of housing (individual or in groups of four) 8 weeks of life (Tables 2 and 3). The breed had a significant effect on WLOSS, with the Czech Fleckvieh cows coping better with the post-partum energy challenge and having lower weight loss than Holstein cows during the first 21 days after parturition ($F_{1,20} = 5.83$, $p = 0.026$, Tables 2 and 3, Fig. 1). None of the other five performance variables (SURVIVAL, LONGEVITY, AGEPREGN, MILK, MPERSEC) was affected by the breed.

All cows increased their locomotion on the day after being moved to a new production group compared to the day before the move ($F_{1,97} = 34.38$, $p < 0.001$, Fig. 2). Czech Fleckvieh cows were more active both before and after the move between production groups ($F_{1,99} = 8.49$, $p = 0.004$, Fig. 2). The cow locomotion was not affected either by the time of separation from the mother, by the housing environment or by the interactions of these two effects with the day of measurement (before or after change, Table 2, Fig. 2), thus showing that the change in locomotion after the social challenge was not modified by the different rearing conditions in early ontogeny.

4. Discussion

4.1. Effect of mother on the performance at the first lactation and on the longevity or age at first conception

We did not find any significant influence of the stay of the calf with its mother during the first 4 days of life on the longevity or on production at the first lactation measured as the survival till the first day of

Table 2
Results of analysis of presence of the mother and group housing (COMPANION) during early ontogeny on reproduction, production and behaviour in dairy cows. Bold font indicates a significant result.

Dependent variable	No of animals	Fixed effect	Error term degrees of freedom	F value	p-value
SURVIVAL	40	MOTHER	Chi-Square 0.03		0.862
		COMPANION	Chi-Square 0.33		0.565
		BREED	Chi-Square 0.82		0.364
LONGEVITY	40	MOTHER	36	0.01	0.927
		COMPANION	36	0.08	0.773
		BREED	36	0.58	0.451
AGEPREGN	31	MOTHER	27	1.67	0.207
		COMPANION	27	0.62	0.438
		BREED	27	2.88	0.101
MILK	27	MOTHER	23	0	0.989
		COMPANION	23	0.02	0.897
		BREED	23	1.63	0.214
MPERSEC	27	MOTHER	23	0.03	0.853
		COMPANION	23	0.15	0.700
		BREED	23	1.70	0.205
WLOSS	24	MOTHER	20	2.57	0.124
		COMPANION	20	0.09	0.765
		BREED	**20**	**5.83**	**0.026**
LOCOMOTION	29	MOTHER	99	0.00	0.947
		COMPANION	99	0.16	0.690
		BREED	**99**	**8.49**	**0.004**
		DAY	99	**34.80**	**< 0.001**
		MOTHER*DAY	99	0.11	0.740
		COMPANION*DAY	99	1.77	0.186
		BREED*DAY	99	0.14	0.705

Table 3
Least Square Means (± SE) for tested dependent variables.

Tested dependent variable	Fixed Effect					
	Mother		Companion		Breed	
	0 days	4 days	Individual	Group	Czech Fleckvieh	Holstein
SURVIVAL*	0.909 ± 0.56	1.041 ± 0.53	1.192 ± 0.59	0.758 ± 0.5	0.607 ± 0.65	1.344 ± 0.46
LONGEVITY	1272 ± 227	1299 ± 210	1243 ± 227	1328 ± 210	1159 ± 281	1412 ± 171
AGEPREGN	476 ± 14	452 ± 13	457 ± 13	471 ± 14	446 ± 18	482 ± 11
MILK	7113 ± 559	7123 ± 549	7166 ± 559	7070 ± 549	6583 ± 717	7653 ± 425
MPERSEC	67.7 ± 5.7	69.1 ± 5.6	69.9 ± 5.7	67 ± 5.6	62.9 ± 7.3	74 ± 4.3
WLOSS	0.96 ± 0.01	0.98 ± 0.01	0.97 ± 0.01	0.96 ± 0.01	0.99 ± 0.02	0.95 ± 0.01

* LS means for logit values.

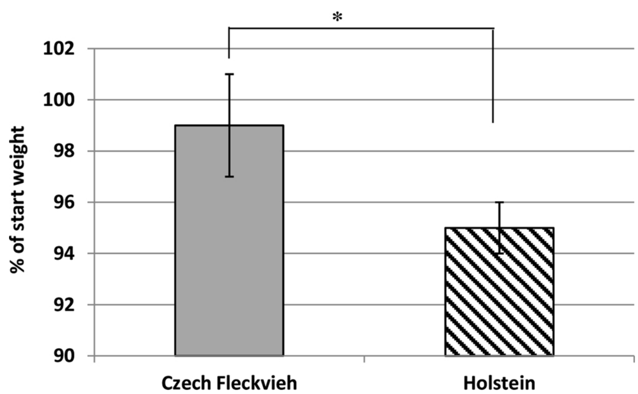

Fig. 1. Effect of breed on weight loss at 21 days of lactation. LS Means Estimates ± SE, „* "represents $p < 0.05$.

the first lactation, age at first successful conception, sum of the milk yield during the 305 days of first lactation, the average speed of milking during the 305 days of first lactation, body weight loss during the first three weeks of lactation or the change in locomotion around the group changes.

The calves nursed by their mothers had opportunity to drink larger amount of colostrum in several suckling sessions compared to the early separated calves, who received only 4 L of colostrum per day in two feeding sessions (Valníčková et al., 2015). This feeding management might have an important effect for the further calf´s development such as higher motivation to perform play behaviour in later age (Stěhulová et al., 2008; Valníčková et al., 2015), higher initial body weight gain (Flower and Weary, 2001; Valníčková et al., 2015) and better health (Flower and Weary, 2001). The stay with the mother lasted just 4 days which was probably too short for showing any influence on the studied variables that were measured at least 1 year later. The 4 days bring only a time-limited advantage in milk intake and therefore the higher body weight disappeared within 2 weeks after separation of calves from mothers (Valníčková et al., 2015). This corresponds with a previous study, where the calves were also housed with their mothers only for 4 days) and no significant influences on weight gain of these calves were found (Krohn et al., 1999). On the other hand a study where calves were kept with their mothers for a whole week after birth showed larger milk production in first lactation (Brouček et al., 2006). Also calves reared with foster cows up to 8 weeks of age had higher weight gain during this time and later tended to have the highest production of milk at the first lactation (Brouček et al., 2006). These differences between studies might show that period of 4 days is not long enough to achieve a significant long-lasting effects on reproductive and lactation performance of observed animals.

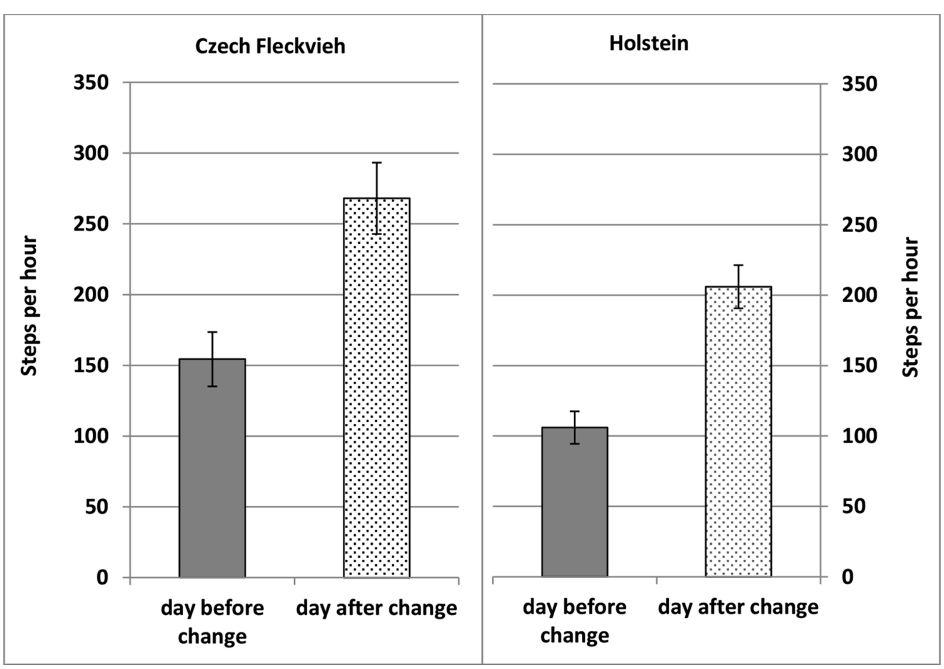

Fig. 2. Cow activity after introduction to the new social environment. LS Means Estimates ± SE.

Another positive factor of stay with the mother can be a better development of social skills (Weary and Chua, 2000; Flower and Weary, 2001). This can be caused by the presence of a social companion. Cattle are considered a hider species with calves staying individually hidden in the vegetation and awaiting the mother appearance, which means that during the first week of its life the calf's only and first social partner is usually the mother and with her help the calf is learning its first social skills (Le Neindre and Sourd, 1984; Vitale et al., 1986; Lidfors and Jensen, 1988). The better social skills may help the animal later in life in social group organization and in interactions with other animals. However, the 4 days might be not enough to form and preserve these skills. Under natural conditions, cattle form matrilineal herds where females stay in their natal herds during the whole life (Lazo, 1994). Thus, relationships between mothers and their daughters might be as close in cattle as they are in the related species of American Bison *(Bison bison)* (Green et al., 1989; Green, 1993) that also stay together for life. These life-history facts suggest the possibility that when a heifer is raised in a company of her dam, her physical and psychological development is probably positively affected, thus enhancing her welfare. The question is if staying with mother for 4 days does not stress cow and calf more by separation and breaking the freshly established mother-young bond.

4.2. Effect of companions on the performance at the first lactation and on the longevity or age at first conception

To our knowledge, this is the first study to examine how group housing of female dairy calves during the first weeks of life affects their later performance. We did not find any significant influence of presence of companions provided by the group housing on the tested variables. Despite the higher weight gain in socially housed calves up to weaning at 8 weeks of age (Valníčková et al., 2015; Pempek et al., 2016), this advantage started to disappear after mixing with other animals (Valníčková et al., 2015) and became undetectable after 10 weeks of age. Under natural conditions, calves start to associate with other peers approximately at the age of 2 weeks after birth (Le Neindre and Sourd, 1984) and later also engage with other animals in the herd, thus engaging in a rich social life. In accordance, a positive effect of social housing on social skills (measured in weeks) has been demonstrated in dairy cattle (Jensen et al., 1998). Potentially, better social skills could translate in better health and/or higher performance. However, we did not find any influence (positive or negative) of group housing on survival, first lactation performance or locomotion after moved into another group in mature dairy cows. While this study failed to document any positive effects, it also found no negative effects. This indicates that farmers adopting the group housing methods for calves need not fear alleged detrimental influences on the animals' future performance in terms of longer service period, deeper post-partum weight loss or increased mortality. Thus, in practical farming, housing of calves in small groups should be compared with its alternatives such as individual housing, pair housing ((Abdelfattah et al., 2013; Bučková et al., 2019; Reiten et al., 2019) or housing in larger groups ((Svensson and Liberg, 2006), Costa et al., 2016) from a perspective of the short-term effects on calves performance, health and welfare during the milk feeding period of life.

While our study did not find any effect of early group housing on later female dairy cattle traits, we cannot conclude that such effects do not exist. Our study focused on first lactation only, with the exception of longevity. The study was also limited in the number of measured parameters. For instance, we collected just one indicator of cows' reaction to group change (locomotion), which does not give the full picture of social reactions and social behaviour in the group. Cows preferably interact with animals they know from previous time (Gutmann et al., 2015) and (Duncan and Meyer, 2018) their locomotion behavioural reactions are affected by parity (Calderon and Cook, 2011; Duncan and Meyer, 2018) and neither of these aspects could be evaluated in our study. Thus, the further studies on long-term effects of social environment in early ontogeny on social development and social abilities of dairy heifers and cows are needed.

4.3. Effect of breed and management on weight and locomotion of cows

Free range cows spend usually whole life in herd where they were born (Lazo, 1994). When two different herds meet, or when a new cow is introduced to the herd, animals employ agonistic behaviour to establish a hierarchy (Lamb, 1975; Orihuela and Galina, 1997). Our results show significant increase of locomotion after cows were moved between groups during the lactation. Part of this enhanced locomotion was probably connected with agonistic behaviour and establishing social hierarchy, especially because the first-lactation cows met many cows in the new group for the first time in their life. Although we did not find any significant effect of presence of mother first 4 days after birth nor an effect of group housing on activity after moving animals to new groups, we found a significant influence of breed. Holstein cows were less active than Czech Fleckvieh cows both before and after introduction into new group. This result can be linked with our other finding that Holstein cows lost significantly more weight during first 21 days of lactation than Czech Fleckvieh cows. Holstein primiparous cows were found to lose more weight than Czech Fleckvieh primiparas during the first weeks of lactation also in a larger sample studied by Řehák et al., 2012). Deeper body mass loss indicates a stronger squeeze in available energy in the Holsteinswhich could reduce their motivation for locomotor activity..

5. Conclusion

This study did not find any difference in performance at the first lactation or in longevity in female cattle that had been housed 4 days after birth with its mother or separated immediately after birth and then housed either in groups of four or individually up to 8 weeks. The results indicate that neither provision of maternal care for a few days nor group housing for the duration of milk feeding bring any advantage or disadvantage for the first lactation performance in dairy cattle. We conclude that from the point of the examined long-term effects, these early housing method are on par with the traditional individual housing of dairy calves.

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4.3 Data I- Productional data of primiparous dairy cows reared in different social environments during the first 8 weeks after birth (Valníčková et al., 2022)

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Data Article

Productional data of primiparous dairy cows reared in different social environments during the first 8 weeks after birth

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Dataset link: Productional data of primiparous dairy cows reared in different social environments during the first 8 weeks after birth (Original data)

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Group housing
Rearing conditions
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Activity
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Longevity
Performance

ABSTRACT

This paper is composed of 5 datasets describing primiparous milk production, reproduction, body weight, activity and whole life longevity and reproductional data in dairy cows that had been reared either with or without mother for the first four days after birth and either in single housing or housing in groups of four between 1 and 8 weeks of age. The datasets contain the following variables- survival to the first lactation, date of first successful insemination, milk parameters per day (such as sum of milk yield, milk electrical conductivity and milking time), activity and body weight, all these collected during the first standardized lactation of 305 days. Cows' longevity, reproduction and other management events were recorded during the whole life of experimental animals (such as inseminations, pregnancy diagnostics, group changes etc.). Calves' body weight was measured first 12 weeks of life of the experimental animals. The data include the information about the type of housing (with or without mother, individual vs group housing) in the early ontogeny period and two different breeds (Holstein and Czech Fleckvieh). Data on the milk parameters, body weight and activity were collected twice a day by commercially used precision dairy monitoring technologies. Data on survival to

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the first lactation, longevity, first successful insemination and other events were recorded by farm managers on farm basis. Data on body weight of animals during early ontogeny were taken after birth, at 4 d of age, at 7 d of age, and then weekly until 12 weeks of age. The data can be used for further analyses of the influence of parameters from early ontogeny on cow performance, especially during the first lactation. This information can be useful for researchers and other stakeholders investigating the influence of early ontogenetic social environment on the dairy cattle performance and welfare.

Specifications Table

Subject	Animal Science and Zoology
Specific subject area	Dairy cattle management and production
Type of data	Table
How the data were acquired	Electronic scale: Eziweigh2, Tru-Test Ltd., Auckland, New Zealand- calf weight (kg) Commercially used precision dairy monitoring technologies measuring physiological, behavioral, and production variables for individual animals: Dairy management systems made and produced by company Afimilk Ltd. Programmable milking point controller: AfiMilk MPC™ milk meter- milk yield (g), milk electrical conductivity (mmHO), milking time (sec) Accelerometer sensors: Afitag pedometers on left hind leg- activity (e = number of steps) Weighting system: automatic walk- over weighting system AfiWeight- weight of dairy cows (kg) Anntenas: IDeal Afi identification systém, the identification system's sensors and active identification sequence in Afi systems-Transfer of data from sensors to AfiFarm™ software Veterinary and management records: written by hand of farm manager to the Afifarm™ 4.1 [1] software- All measurements in „Events“ dataset (see Tab. 2) All data were taken within the daily routines of commercial dairy farm Software: Afifarm™ 4.1 [1]- Data collection SAS 9.4 [2]- Data filtration
Data format	Raw Filtered
Description of data collection	Calves were randomly allocated to treatments "Mother" and "Housing". They were weighted 3 times in first week and then weekly for 12 weeks. During lactation data were collected after milking by precision dairy monitoring technologies. For numerical variables, one final number for each variable was given per day. Other data were collected manually. For description of variables see Tables 1 and 2.
Data source location	Institution: Institute of Animal Sciences City: Prague Country: Czech Republic Latitude and longitude (and GPS coordinates) for collected data: 50°02'19.7"N 14°36'36.0"E
Data accessibility	Repository name: Mendeley Data Data identification number: 10.17632/j42n4x723g.2 Direct URL to data: https://data.mendeley.com/datasets/j42n4x723g/2
Related research article	B. Valníčková, I. Stěhulová, R. Šárová, M. Špinka, The effect of age at separation from the dam and presence of social companions on play behavior and weight gain in dairy calves, Journal of Dairy Science, 98 (2015) 5545-5556 [3]. https://doi.org/10.3168/jds.2014-9109 B. Valníčková, R. Šárová, M. Špinka, Early social experiences do not affect first lactation production traits, longevity or locomotion reaction to group change in female dairy cattle, Applied Animal Behaviour Science, 230 (2020) 105015 [4]. https://doi.org/10.1016/j.applanim.2020.105015

Value of the Data

- This dataset shows association of different types of housing during early ontogeny in calves and milk production, body weight (in early ontogeny and in first lactation) and activity in dairy cows during their first lactation in two different breeds.
- These data can be beneficiary for researchers and other stakeholders working in cattle welfare improvement.
- These data can be further used for analysis or metanalysis of cow's production with connection to early ontogeny rearing and welfare.
- High quality data are possible to provide by commonly used commercial precision dairy monitoring system.
- These data can be further used for dairy cattle welfare improvement
- These data can be further used for assessment of welfare indicators in dairy systems.

1. Data Description

We submit five data sets, which were recorded by commercially used Precision dairy monitoring technologies measuring physiological, behavioral, and production variables for individual animals. For closer description of all variables in all datasets please see the Tables 1 and 2.

The first data set is called "Survival", and it shows the experimental treatment of animals, age when experimental animals were culled and whether they survived until their first lactation.

The second data set is named "Service period" and shows the experimental treatment of animals and the date of their first successful insemination. The insemination was considered successful if it was later confirmed as a successful pregnancy.

The third dataset is called "Daily data" and shows daily data of primiparous cows about milk yield, milking time, milk electrical conductivity, body weight and activity of every experimental animal until the end of the standardized lactation (305 days) or death of the animal if it occurred before the end of the first lactation.

The fourth dataset is called "Events" and shows a selection of important veterinary or management events and procedures which experimental animals underwent during their whole life from birth until their exit from the herd (culling or death).

The fifth dataset is called "Calf weight" and shows the body weight of the experimental animals when they were born, at 4th day, 1st week and then every week until 12th week of their life.

Filtered datasets are Survival, Service period and Milk yield which were formed with the use of Daily data and Events datasets. Daily data, Events and Calfweight are raw data.

2. Experimental Design, Materials and Methods

2.1. Animals and Experimental Procedures

All observations were realized at the experimental farm of the Institute of Animal Science in Prague, Czech Republic. In the experiment, 40 female calves of two breeds of domestic cattle (11 Czech Fleckvieh and 29 Holstein) were used, corresponding to the composition of the dairy farm herd. Data about experimental animals were collected from their birth until their death/ exit from the farm. Experimental heifer calves were randomly allocated, at the time of their birth, to one of four treatments according to a two factorial design, which gave 4 treatments in total: 0 days with mother x 4 days with mother and after single housing x group housing.

The first treatment differentiated between those calves kept with and those without their *mother* during the first 4 days after parturition. The calves were kept with their mothers in a

Table 1
Description of individual variables in all datasets.

Name of the variable	Description of variable	Dataset name
CowID CalfID	ID -registration number of the individual animal	- Survival - Service period - Milk yield - Daily data - Calfweight
Mother	When calf was separated from the mother 0 - during 24 h post partum 4 - 4th day post partum	- Survival - Service period - Milk yield - Calfweight
Housing	Housing of the calves after separation from mother until 8 weeks of age I – individually G - groups of 4 calves	- Survival - Service period - Milk yield - Calfweight
Breed	H - Holsein cattle C - Czech Fleckvieh cattle	- Survival - Service period - Milk yield - Calfweight
Date	Date of the measurement	- Daily data
1st lactation survival	Did the heifer survive until the start of the first lactation? YES - the heifer started her first lactation in the herd NO - the heifer died or was culled before first calving	- Survival
Exit age	Age in days when animal was culled	- Survival
Age pregnancy	Age in days when heifer was successfully inseminated (and later confirmed as pregnant).	- Service period
Sum of milk	Total milk yield in grams for standardized lactation (305 days).	- Milk yield
Group	Number of the group where animal is placed on this date	- Daily data
Yield(gr)	Total daily milk yield in grams	- Daily data
Conductivity	Maximal electrical conductivity of the milk measured given day in (mmHO)	- Daily data
Milking_Time(Sec)	Milking session in seconds, higher number from two daily milkings was reported	- Daily data
Body Weight(kg)	Average weight of the animal in kilograms per day	- Daily data
Activity(steps/hour)	Number of steps per hour- Highest value measured this day was reported	- Daily data
Birth 4days 1weeks-12weeks	Body weight in kilograms weighted in birth, 4 days, 1st -12th week of life of experimental animal	- calfweight

straw-bedded calving pen (4 × 3 m) until separation.After their separation from the mother all calves were housed individually until 1 week of age, to ensure that they knew how to drink milk from an open bucket.

A *companion* treatment was applied thereafter, which distinguished between calves reared with 3 other social companions in *group* pens and calves reared in *individual* pens between 1st and 8th weeks of age. The individual pen composed of an individual plastic hutch (1.2 × 1.4 m, 1.7 m^2) and an outside run (1 × 1.2 m, 1.2 m^2). The calves in individual pens had visual but not tactile contact with two other calves in the neighbouring pens, as a gap of 40 cm was left between them. The *group* pen consisted of 4 individual plastic hutches (4 × 1.7 m^2) connected

Table 2
Description of individual events.

Name of the event	Description of the event
Abortion	Natural loss of an embryo or fetus before it is able to survive independently.
Birth	Birth of the focal animal
Calving	Give birth to a calf
Dry	Ending milk production period of the cow before the next calving or exit from the herd
Entry	Entry animal to the herd due to birth or purchase
Exit	Exit animal from the herd due to death or sale
Heat	Female sexual receptivity in oestrus
Change Group	Move of the animal from one group to another
Insemination	Introduction of sperm into a female's cervix for the purpose of achieving a pregnancy
Not for Insemination	Animal is defined by the herd manager not for insemination
OK Not Pregnant	Animal confirmed not pregnant after examination
PD(+)	Animal confirmed pregnat after examination

by the central outside run (4×1.2 m^2). All hutches had solid concrete floor, and were richly bedded with straw (4 kg of straw/calf, huts were cleaned and added new straw 3 times per week). The outside run had solid floor made of concrete, that was cleaned once a week. After the separation of calves from their mother, calves were fed 2 L of milk (or colostrum before 5 days of age) twice a day from open buckets until 8 weeks of age. All calves had ad libitum access to hay, starter mixture and water during the entire rearing period.

In the *group housing*, 2 heifer calves and 2 bull calves of similar age were housed together in each of 20 groups, but only 1 heifer in each group was monitored as the experimental animal. Thus, we observed 40 experimental animals in total, 10 experimental animals per each treatment. The calves were randomly assigned to the 4 treatments. The breed of the calves and the sex could not be fully randomized across the treatments due to the farm conditions. The *group housing* was moderately balanced for breed at the beginning of the experiment (Holstein to Czech Fleckvieh ratio was 16:4 in the *individual housing* treatment and 13:7 in the *group housing* treatment) and nearly balanced at 12 weeks of age (14:4 individual housing, 12:4 group housing). The treatment of calves kept first 4 days after birth with or without mother was not balanced in terms of breed neither at the beginning (the breed ratio being 17:3 in calves immediately separated from mother and 12:8 in calves kept with mothers) nor at the end of the experiment at 12 weeks (the breed ratios being 15:1 and 11:7, respectively).

At 8th week of age, all calves were weaned abruptly from the milk and moved at the same time to a large group pens. After weaningthey had ad libitum access to a starter mixture, hay and water. Calves coming from the *individual housing* treatment were grouped with 3 unfamiliar calves (1 female calf and 2 male calves). Calves in the *group housing* treatment were moved to a new group pen together with their penmates and therefore their social environment did not change. In each of the groups, only 1 female calf was a focal animal. Calves were kept in these large group pens until 12th week of age. Large group pens consisted of a plastic hut (9 m^2) and an outside run (9 m^2). All areas had a solid concrete floor, and the hut was heavily bedded with straw (16 kg of straw, huts were cleaned and added new straw 3 times per week).

Starting at 12 weeks of age, all experimental animals became part of the production herd and they were submitted to the routine farm management together with all other female cattle on the farm.

After 12 weeks of age, the calves were moved to groups of 24 heifers where they were later inseminated (between 13 and 18 months of age) and stayed there until late gestation of their first pregnancy (5 month of pregnancy). The age of insemination was dependent on individual body weight and body condition.

At 5 months of pregnancy (late gestation period) the heifers were moved to the group of dry cows where they stayed until calving.

Animals in all mentioned groups were housed freely on solid concrete floor without bedding and with cubicles bedded with straw provided for lying. Number of cubicles was equal to number of animals in the group. Heifers, had access to an outside run with solid concrete floor. Heifers and pregnant heifers in groups were fed once a day with a Total mixed ratio (TMR) based on corn silage, haylage and straw. After entering the group of dry cows, late-gestation heifers were fed once a day with TMR based on haylage, straw and mineral additives. Scattered feed (TMR) was pushed back to the feeding bunk 4 times a day in all groups of heifers, pregnant heifers and dry cows. Before every delivery of fresh feed, old remaining feed was removed if any left.

Just before calving, the heifers in late gestation period were isolated and placed in a straw bedded calving pen. Within 24 h after calving the newly primiparous cows were moved to the group of about 50 lactating cows (GROUP 1). After the peak of lactation, when their milk yield dropped below 24 kg milk/ day, the cows were moved to the next group of lactating cows (GROUP 2) of about 48 animals. When their milk yield dropped further, the cows were moved to the last group of lactating cows (GROUP 3) consisting of approximately 60 animals. Two months before the next calving the cows were dried off and were moved to the group of dry cows (GROUP 4), where they weren't milked until the calving and start thenext lactation.

Lactating cows in all groups were housed freely and all these groups had solid concrete floor without bedding and cubicles bedded with straw. Cows in all groups had access to an outside run with solid concrete floor and cubicles bedded with straw placed under the roof (1 cubicle per cow). Manure from group pens was removed two times per day and straw in cubicles was changed once a week. Lactating cows were fed twice a day with TMR based on corn silage, haylage and straw with mineral and vitamin additives. Scattered TMR was pushed back to the feeding bunk 9 times per day. Before every delivery of fresh feed, all remaining feed was removed. Lactating cows were milked twice a day at 4am and 4pm in a tandem parlour with 3×3 stalls.

2.2. Data Collection

The calves were weighed with an electronic scale (Eziweigh2, Tru-Test Ltd., Auckland, New Zealand) immediately after birth, at 4 d of age, at 7 d of age, and then weekly until 12 weeks of age.

Data about milking, body weight and activity were automatically collected and processed by commercial Precision dairy monitoring systems created and produced by company Afimilk Ltd. Sensors of these systems have been developed with the capability to measure variables for individual cows [5] including milk yield, lying time, milk electrical conductivity [6], number of steps [7], and body weight [8]. Data about milk yield, electrical conductivity of milk and milking duration were measured during every milking by sensors of AfiMilk MPC™ milk meter placed in each milking stall. To get reliable information about electrical conductivity of milk during one milking, each 200 cubic centimetres (cc) of milk is checked while the milk flows through the milk meter [9]. Data about activity were collected through Accelerometer sensors Afitag pedometers placed on left hind legs of all cows.

Each cow was weighed on an automatic walk-over weighing system called AfiWeight, which automatically measures the cow's body weight and saves it in AfiFarm Software[1] database The system consists of a weighing platform installed en-route from the milking parlour, weighing the cows returning from every milking regularly.

A specific Pedometer ID number was assigned to each cow in the AfiFarm software [1] on the cow's card. The pedometer was used for the identification of the cow at the milking parlour and the AfiWeight station, where all measurements of milk production, activity and weight were taken. Data from Afitag pedometers and AfiMilk MPC™ milk meters were automatically collected during every milking, while data from AfiWeight were collected after every milking, when the cow walked over the weighing platform. Immediately after every milking and weighing, the data for each cow were scanned and sent together with the ID number to the central computer via IDeal Afi radiofrequency antenna. The data were then processed and stored by the dairy farm management software AfiFarm™ version 4.1 [1].

The highest number of steps per hour, the weight of milk, the body weight and the highest values of electrical conductivity and milking duration are noted in the AfiFarm™ software after everymilking and weighing sessions. The final numbers of daily data are given by the software after the last milking and weighing session each day. Information about calving, inseminations, pregnancy, transfer of an animal between the production groups and exit of the animal from the farm were added to the software manually by the manager of the farm according to the routine.

Filtered datasets were processed with software SAS 9.4 [2].

Ethics Statements

In the experiment participated 40 females of domestic cattle. The experiment complied with the ARRIVE guidelines and was designed and performed in accordance with EU Directive 2010/63/EU for animal experiments and Czech law 246/1992 Coll. for the protection of animals against cruelty. The protocol was approved by the Institutional Animal Care and Use Committee of the Institute of Animal Science (No. 18/2004).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Productional data of primiparous dairy cows reared in different social environments during the first 8 weeks after birth (Original data) (Mendeley Data).

CRediT Author Statement

Barbora Valníčková: Conceptualization, Methodology, Validation, Investigation, Writing – original draft, Writing – review & editing, Visualization, Data curation; **Radka Šárová:** Conceptualization, Methodology, Validation, Formal analysis, Writing – original draft, Writing – review & editing, Supervision, Data curation; **Ilona Stěhulová:** Conceptualization, Methodology, Validation, Investigation, Resources, Writing – review & editing, Data curation, Supervision, Project administration.

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4.4 Study III- Weaning reactions in beef cattle are adaptively adjusted to the state of the cow and the calf (Stěhulová et al., 2017)

Weaning reactions in beef cattle are adaptively adjusted to the state of the cow and the calf[1,2]

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ABSTRACT: Abrupt weaning as practiced in beef cattle husbandry is stressful for both the cow and her offspring. However, the reaction to weaning varies among individuals. Based on the theory of maternal care allocation, we derived and tested the following hypotheses: 1) cow reaction to weaning will be stronger if the calf is young, if the calf is a female, and if the calf had higher daily weight gain; 2) cows in a higher parity and cows that are not concurrently pregnant will react more on weaning; and 3) young and female calves, and also calves with higher daily weight gain will respond more to weaning. We recorded frequency of vocalization and time spent moving in 50 cow–calf pairs (27 males and 23 females) immediately after weaning at 151 to 274 d of age. The recordings were made at 0 to 2 h, 6 to 8 h, and 24 to 26 h after the separation of the calves from the cows. Linear mixed models were used to test the predictions. In cows, age of the calf had the strongest effect with mothers of younger calves vocalizing more ($P < 0.05$). Frequency of vocalization was higher in mothers of calves with higher daily weight gain ($P < 0.01$) and in nonpregnant mothers ($P < 0.01$). Frequency of the moving was higher in younger cows ($P < 0.05$). Sex of the calf had no effect. In calves, females vocalized ($P < 0.001$) and moved ($P < 0.01$) more than males and calves with higher daily weight gain also called more ($P < 0.01$). The relationships between the 2 behaviors and their time courses were different in cows and calves. In cows, vocalization and movement were correlated ($P < 0.001$) and both increased until 6 to 8 h and then plateaued or declined ($P < 0.001$). In calves, vocalizations steadily increased until 24 to 26 h ($P < 0.001$) whereas movement remained unchanged in time and was uncorrelated with vocalizations. These differences indicate that vocalization may be a more sensitive indicator of weaning stress than movement. Our results document that the ability to adaptively adjust mother–young interactions has been preserved in domesticated beef cattle.

Key words: beef cattle, parental investment, sexual differences, vocalization, weaning stress

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INTRODUCTION

In domestic beef cattle, calves are separated from their dams earlier than the natural time of weaning would occur (Weary et al., 2008). This artificial weaning is stressful for both the cow (Lynch et al., 2010a; Ungerfeld et al., 2011) and her young (Lynch et al., 2010b; reviewed by Enríquez et al., 2011). In contrast to natural weaning, the calves are abruptly separated from their mothers, instantly deprived of milk supply, and exposed to a new environment (Weary et al., 2008). According to the behavioral ecology theory, the reaction to separation should vary according to how much it endangers the survival and growth prospects of the calf. Younger calves and their mothers should strive harder to reestablish the contact as younger calves are less able to prosper on their own. The reaction should also be stronger in calves with higher growth rates and their mothers because higher unrealized growth potential is at stake (Ungerfeld et al., 2009). Third, heifer calves are predicted to react more to the artificial weaning as under natural conditions, female progeny stay in

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the herd for the whole life (Lazo, 1994) and, therefore, continuous maternal contact is more important for them. Additionally, being concurrently pregnant and lactating may reduce the reaction by cows, as they can redirect the resources to the unborn progeny (Bateson, 1994). Finally, the reaction may increase with cow parity as older cows have a lower chance of future reproduction and are, therefore, inclined to invest more into the current progeny (Pianka and Parker, 1975).

Therefore, this study tested the following hypotheses: 1) cow reaction to weaning will be stronger if the calf is young, if the calf is a female, and if the calf had higher daily weight gain; 2) cows in a higher parity and cows that are not concurrently pregnant will react more on weaning; and 3) young, female, and calves with higher daily weight gain will respond more to weaning.

MATERIALS AND METHODS

This study was designed and performed according to European and Czech laws. The protocol received approval for animal use and care from the Institutional Animal Care and Use Committee of the Institute of Animal Science in Prague.

Animals and Housing

The observations were performed in 2001, 2002, 2003, 2010, and 2011 as a part of a wider project aimed at maternal behavior of beef cattle from birth to weaning (e.g., Stěhulová et al., 2013). The observations took place in the beef herd of the Gasconne cattle breed kept at the experimental farm of the Institute of Animal Science in Prague for the meat production. The herd size fluctuated between 26 and 34 adult female cattle due to the inclusion of new heifers and the sale and slaughter of old cows. All of the animals were between 2 and 16 yr of age and were either of pure Gasconne descent or crossbreeds with at least 50% of Gasconne genes. From November each year (2 mo after the calves had been weaned and 2 mo before the calving season started) until April, the animals were kept in a deep-bedded barn (279 m^2) with an adjacent concrete outdoor paddock (1,145 m^2). The herd was pastured for the rest of the year. The calving season started in the beginning of January and terminated in April. During the winter season, animals were fed by a total mixed ration put in the trough once a day, with continuous access to straw. During the pasture season, they had ad libitum access to meadow hay and straw. During the whole year, animals had continuous access to water and a mineral lick. In addition to common ear tags, all animals were marked by numbered plastic collars. For the observation, only the purebred Gasconne cows were chosen.

Table 1. Descriptive statistics of the animals

Category/variable	Median	Q1	Q3	Min	Max
Cows (*n* = 35)					
Parity	4	1	7	1	13
Calves– females (*n* = 23)					
Weaning age	207	198	231	153	274
Daily weight gain	1.05	0.94	1.10	0.59	1.22
Calves– males (*n* = 27)					
Weaning age	201	178	229	151	255
Daily weight gain	1.14	1.01	1.23	0.78	1.48

Weaning Process and Weighing of Calves

The calves were weaned in September when they were between 151 and 274 d of age (Table 1). We recorded the response to mutual separation of 35 cows (15 of them were observed in 2 following years; i.e., we observed the response of 50 cow–calf pairs in total) and their calves (27 males and 23 females). The number of observed cow-calf pairs was 8, 6, 4, 22, and 10, respectively, for the 5 observation years and the number of observers differed in each observation year (4 in 2001, 4 in 2002, 2 in 2003, 8 in 2010 and 4 in 2011). The separation process started at 0800 h and lasted about 1 h. Experimental cows and calves were placed in a crate and marked with colored numbers on both sides of their body in addition to ear tags and numbered collars. All of the animals were weighed during marking, immediately before separation. An electronic scale (Ezi-Weigh; TRU-TEST Ltd., New Zealand) was placed in the crate and covered by a steel plate. After weaning, at approximately 0900 h, the cows stayed in the barn with free access to the pasture. The calves were moved to another building to 1 of 2 group pens, 1 for heifer calves and 1 for bull calves. The 2 groups of calves were divided by an iron bar barrier and thus could have visual and auditory contact and partial physical contact. The distance between the barn and the building for calves was about 50 m and it took about 10 to 15 min to move the calves. There was no visual contact between the mothers and their calves after weaning, but they could hear each other's vocalizations.

Behavioral Observations

The reaction of both the cows and the calves was quantified using 2 categories of behavior. Frequency of vocalizations was recorded as an indicator of communication efforts and time spent moving was recorded as a measure of active striving to locate the lost progeny/mother.

The observations started immediately after separation. The behavior of the cows and their calves was recorded in three 2-h sessions, between 0 and 2 h, between 6 and 8 h, and between 24 and 26 h after weaning. The instantaneous sampling in 3-min intervals

Table 2. Results of mixed linear models on post-weaning vocalization and moving of cows

Fixed effect	Item	Vocalization (log frequency)	Moving (proportion of time)
Weaning age	Result	Cows of younger calves vocalize more	NS[1]
	df	88	106
	F-value	5.28	0.01
	P-value	0.0240	0.918
Daily weight gain	Result	Cows of calves with higher DWG vocalize more	NS[1]
	df	88	106
	F-value	7.44	2.05
	P-value	0.008	0.155
Sex	Result	NS[1]	NS[1]
	df	88	106
	F-value	0.80	0.04
	P-value	0.373	0.833
	LS Means		
	Females	24.3[2]	0.122
	Males	19.7[2]	0.126
Next pregnancy	Result	Nonpregnant cows vocalize more	NS
	df	88	106
	F-value	8.25	1.48
	P-value	0.005	0.226
	LS Means		
	Nonpregnant	30.7[2]	0.135
	Pregnant	15.6[2]	0.114
Parity	Result	NS	Younger cows move more
	df	88	106
	F-value	0.67	5.62
	P-value	0.415	0.020

[1]nonsignificant.

[2]Geometric LS means (number per h).

was used to record the time spent moving (animal was walking, all 4 legs moving) as locomotion behavior. Continual sampling was used to record the frequency of vocalization (1 call followed by breath intake, and each call was recorded as 1 occurrence). All the observers were previously trained in observations. The number of animals per observer was 4 to 6.

Statistical Analysis

To estimate the effects of the examined factors in response to weaning, mixed linear models (SAS 9.2; PROC MIXED, unstructured covariance structure; SAS Inst. Inc., Cary, NC) were applied with cow–calf pair identity as a random repeated effect and with year and cow identity as random effects. Fixed factors in calf behavior models were weaning age and daily weight gain (from birth until weaning) as continuous effects and sex as a categorical effect. In cow behavior models, the same 3 fixed effects plus pregnancy (i.e., whether the cow was pregnant when her calf was weaned) as a categorical effect and parity as a continuous effect were included. In all models, periods of observations (0 to 2 h, 6 to 8 h, and 24 to 26 h after separation) were included as repeated measurements. The dependent variables in the models were the proportion of time spent moving and the frequency of vocalization which was log transformed to get normal distribution of the data. We also calculated Pearson correlations between cow vocalization and movement and between calf vocalization and movement. This was done to assess our assumption that the 2 behavioral variables are indicators of one underlying motivation, namely the effort to reestablish the mother–offspring contact.

RESULTS

Descriptive Statistics

The descriptive statistics of the cows' parities and the calves' weaninig ages and daily weight gains are given in Table 1. The cows' parities had a left skewed distribution. Female and male calves did not differ in their weaning age (*t* test, $t = 0.96$, $P = 0.34$). Bull calves had higher daily weight gains than heifer calves (*t* test, $t = -2.78$, $P < 0.01$).

Cow Response to Weaning

Post-weaning vocalization of the cow was affected by weaning age and daily weight gain of the calf as well by the pregnancy of the cow, in agreement with our hypotheses (Table 2). The younger the calf was at weaning, the more its mother vocalized after the separation. Furthermore, the cows with faster-growing calves vocalized more, and cows that were not pregnant vocalized

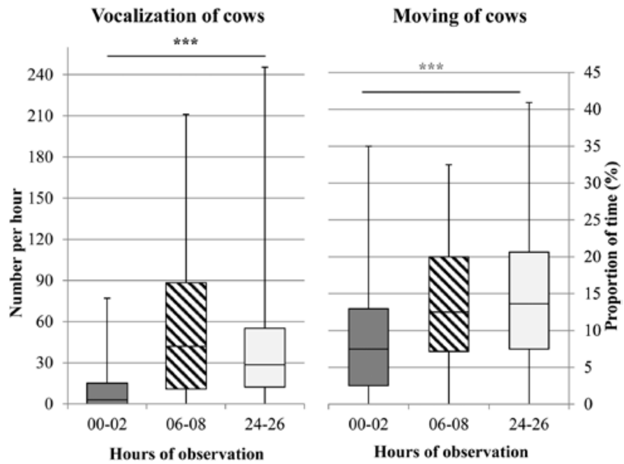

Figure 1. Time progression of post-weaning cow behavior on hours 0 to 2, 6 to 8 and 24 to 26 after weaning (median, quartiles and minimum/maximum are depicted by the box and the whiskers, respectively). The 3 asterisks (***) denote significant effect of hour ($P < 0.001$).

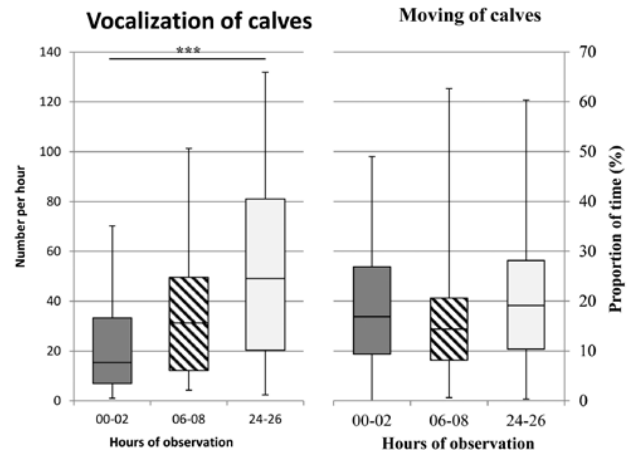

Figure 2. Time progression of post-weaning calf behavior on hours 0 to 2, 6 to 8 and 24 to 26 after weaning (median, quartiles and minimum/maximum are depicted by the box and the whiskers, respectively). The 3 asterisks (***) denote significant effect of hour ($P < 0.001$).

more than pregnant mothers. Sex of the calf had no detectable effect on the cow behavior. Higher parity cows moved less during the post-weaning period (Table 2).

The post-weaning behavior changed within time after the mutual separation (Fig. 1). In cows, the frequency of vocalizations was relatively low immediately after weaning and substantially increased up to 6 to 8 h but dropped slightly until the next day ($P < 0.001$, $F_{(2, 88)} = 30.74$). The time spent moving was low after separation and increased at 6 to 8 h after separation and remained at the similar level until next day ($P < 0.001$, $F_{(2, 106)} = 11.89$).

Cows that vocalized more after separation also spent more time moving ($r = 0.629$, $P < 0.001$), confirming that these 2 variables could be considered indicators of one and the same process.

Calf Response to Weaning

Heifer calves vocalized and also moved much more than the bull calves (Table 3). Furthermore, calves that grew faster from birth to weaning vocalized more frequently after weaning (Table 3).

The frequency of vocalization was high immediately after weaning and increased even more by 6 to 8 h and again at 24 to 26 h after weaning (Fig. 2; $P < 0.001$, $F_{(2, 139)} = 20.54$). The time spent by moving did not change over time (Fig. 2; $P = 0.648$, $F_{(2, 139)} = 0.47$).

Frequency of vocalizations and time spent moving were unrelated in the weaned calves ($r = 0.207$, $P = 0.150$), indicating that the 2 variables could not be considered indicators of one and the same process.

Table 3. Results of mixed linear models on post-weaning vocalization and moving of calves

Fixed effect	Item	Vocalization (log frequency)	Moving (proportion of time)
Sex	Result	Female calves vocalize more	Female calves move more
	df	139	139
	F-value	821.64	8.28
	P-value	< 0.001	0.005
	LS Means		
	Females	46.2[2]	0.253
	Males	18.8[2]	0.185
Weaning age	Result	NS[1]	NS[1]
	df	139	139
	F-value	0.85	3.47
	P-value	0.356	0.065
Daily weight gain	Result	Calves with higher DWG vocalize more	NS[1]
	df	139	139
	F-value	8.98	1.46
	P-value	0.003	0.223

[1]non-significant.

[2]Geometric LS means (number per h).

DISCUSSION

Our study provides evidence that reaction to artificial weaning in beef cattle depends on several characteristics of the cow and calf. Parental investment theory predicts that mammalian mothers balance the allocation of their investment (such as nurturing, protection, and attention time) between the current and future progeny such that their lifetime reproduction output is maximized. For instance, if the progeny is vulnerable or if the mother has a lot of resources, then maternal efforts should be strong. On the other hand, if the progeny is more independent or if the maternal resources are limited, the mother should limit the care of the current offspring and thus spare resources for future reproduction. In this study, we found that some but not all of the hypotheses derived from this theory were supported by data on weaning reactions of beef cows, as discussed below.

Cow Response to Weaning

In agreement with our hypothesis, cows of younger calves tried harder to reestablish contact with their calves, both through more frequent vocalizations and through enhanced locomotion. A recent study by Pérez-Torres et al. (2016) also found that cows with younger calves vocalized more when separated from their progeny, although their study was made at a much earlier age (either 25 or 45 d). It is well documented that the mother–young bond in cattle and related artiodactyls gradually weakens as the calf gets older, as reflected, for example, in the average duration of suckling bouts (Lidfors et al., 1994) or in the cow–calf physical proximity (Veissier et al., 1990). Our study is the first to show that these changes in mother–young bond clearly affect the weaning reaction of beef cow mothers.

Maternal milk output is the most costly investment of the cow into the growth of her calf, although its importance for the calf weight gain may decrease in time. We predicted that cows of calves with higher daily weight gain would react more to weaning as the separation took away a higher future benefit from their progeny. The prediction was supported in vocalization but not in movement, indicating that this factor affects the cow behavior less strongly than the calf age.

As the heifers usually do not leave the native herd (Lazo, 1994), it follows that maintaining mother–daughter bonds, compared with mother–son bonds, should have a higher adaptive value, and therefore we predicted that the cows will react more to the weaning of daughters than to the weaning of sons. However, this prediction was not supported. Our study is, as far as we know, the first one investigating the effect of calf sex on beef cow reaction to weaning, and therefore, further studies would be beneficial to either support or revise our negative finding. This will be interesting as other aspects of cow maternal care, such as initiating contact or maintaining proximity, have been shown to be affected by the calf sex (Stěhulová et al., 2013).

A further prediction was that pregnant cows would resist the separation less as their need to support the sucking progeny is counterbalanced through the need to spare resources for the progeny in the womb. The prediction was supported for vocalization frequency but not for time spent moving. No comparable beef cattle data exist, but similar results were reported in bison by Green et al. (1989), who found that parturient mothers spent less time close to their daughters than barren cows. Nevertheless, the effect of concurrent pregnancy on investment into the suckled offspring may vary according to the stage of lactation. For instance, Bartošová et al. (2011) found that pregnant mares provided more suckling opportunities to their foals in the early stages of lactation than nonpregnant mares, perhaps in compensation for the fact that they wean their foals earlier. In beef cows, further research should investigate how the allocation of different resources shifts from the current to the future progeny across lactation.

We predicted that older cows may react more to the separation because it is adaptive for them to invest much in the current progeny, given that their prospects for future reproduction are limited. However, there was no parity effect on vocalization and, contrary to our prediction, there was a negative effect of parity on movement of the cow. One possible interpretation of this result is that this parity effect on locomotion is unrelated to the weaning procedure and rather is a consequence of the younger cows being generally more agile. As with concurrent pregnancy, the parity effect on maternal reaction to separation may depend on the stage of lactation. Therefore, Price et al. (1986) showed that experienced cows were more sensitive to the separation from calves than nonexperienced cows but their study was performed within the first week of life of the calves. Green (1993) showed in bison (*Bison bison*) that the effort of young bison mothers to keep contact with the calf gradually increased over the months of lactation, whereas old mothers initially maintained very frequent contact but then their efforts decreased.

Calf Response to Weaning

The age at weaning did not affect vocalization rates of the calves and the amount of movement was positively related to age. These findings are contrary to our hypothesis that younger calves will react more because they would benefit more from continuation of maternal care. These results also differ from the study of Lambertz et al. (2015), who showed that younger calves weaned at 6 mo vocalized more than calves weaned at 8 mo. We do not have a good explanation of the nonsignificant result on vocalization. As for the unexpected positive relationship between age and movement, one possibility is that movement is in fact not a good measure of post-weaning stress in calves, as we discuss later in the Discussion.

Faster-growing calves vocalized more after weaning, in agreement with our hypothesis and with the results in cows. One possible interpretation is that fast-growing calves were those that received greater milk supply through, for example, more frequent nursing (Ungerfeld et al., 2009; Stěhulová et al., 2013) and therefore were more affected by weaning than calves that were more independent and have less to lose through the separation. This finding is in agreement with the study of Ungerfeld et al. (2009) in which calves of higher milk producing cows reacted more to weaning. On the other hand, the study of Hötzel et al. (2010) did not show any differences in reaction of calves reared by high production or low production cows to weaning. However, this result may be influenced by the weaning procedure, as calves in this study were prevented from suckling and not separated from their dams.

Females vocalized more than twice as much as males, supporting our prediction that heifers have more to lose from weaning than bull calves. This result is in agreement with another study where female calves weaned at 6 or 8 mo vocalized more than bull calves during the first day after separation (Lambertz et al., 2015). It has been also shown that until 6 mo of age, heifer calves spent more time within 50 m of their mothers than bull calves did (Lidfors and Jensen, 1988) and usually remain attached to their dam long after their weaning (Reinhardt and Reinhardt, 1981; Green et al., 1989; Veissier and Le Neindre, 1989; Veissier et al., 1990; Enríquez et al., 2011). This all corresponds to the natural conditions, where heifers stay in the same herd the whole life unlike bulls, which eventually leave the herd (Lazo, 1994). On the other hand, a study by Hickey et al. (2003) showed that the bull calves dealt worse with abrupt weaning than heifers. But Hickey et al. (2003) observed only noradrenaline in blood of weaned calves and performed no behavioral observation during the weaning process. In light of this, there might be difference between physiological and behavioral reactions of calves to weaning.

Vocalization and Movement as Indicators of Weaning Stress

In the cows, the vocalization rate correlated with time spent moving, and both these behaviors had a similar course over the 3 observation periods. Therefore, these behaviors seem to be expressions of one motivational state, that is, the drive to get back the offspring. In the calves, the 2 behaviors were uncorrelated and had a totally different time course. Although the vocalization frequency steeply increased over the 3 observations, the time spent moving remained unchanged during the 24 h. As the increase in vocalizations corresponds to the findings of previous studies (Lambertz et al., 2015), we conclude that in calves, vocalization is a manifestation of the motivation to contact the lost mother whereas the movements are driven by a different behavioral system, such as the need to accommodate the new environments.

In both the cows and the calves, the vocalizations were more affected by the cow and calf characteristics than was the time spent moving, suggesting that acoustic communication is a more sensitive indicator of the weaning distress. However, one limitation of our methods was that we did not distinguish between different types of locomotion such as walking, pacing, turning around etc. It is possible that other significant effects could have been determined if we had recorded separately the different movement types.

Another limitation of our study is that we could not disentangle the various social mechanisms underlying the weaning reactions. For instance, there could be social facilitation effects in which vocal and/or locomotor activity of one animal stimulated the same behavior in another individual. On the other hand, there could also have been social support effects in that the presence of peers mitigated the behavioral response to weaning. Experimental studies using manipulated environments would be needed to assess these social mechanisms.

Management Implications and Summary

The strongest factor affecting the cow reaction was the age of the calf. Therefore, weaning beef calves early stresses the cow. Nevertheless, our results also show that the cow reaction peaks within the first day, and therefore, the welfare problem may not be long-lasting. This interpretation is in line with the findings of Veissier et al. (1990), who showed that the attachment of mothers to their young is more short-lived after weaning than that of calves to their mothers.

Furthermore, our finding that male calves cope with weaning distress better than females fits the practice used in some beef herds that bull calves are removed from the herd earlier to prevent premature breeding.

In sum, this study shows that cow and calf reaction to abrupt weaning, as expressed in vocalizations and movement, is affected by the individual condition of the mother and the offspring. Cow reactions were reduced if the calf was older and if the cow was concurrently pregnant. Calf reactions were stronger in females compared with males. For both cows and calves, the reactions were stronger if the calf grew faster before weaning. These results document that the ability to adaptively adjust mother–young interactions has been preserved in domesticated cattle. The findings could be also taken into account in the current efforts to make weaning less stressful in practical husbandry, e.g., through fenceline or two-step weaning (Price et al., 2003; Ungerfeld et al., 2015).

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5 Summary discussion

In Study I, we found that social housing has a significant effect on the behaviour and growth of the calves. The presence of mother after birth may increase later playfulness, as higher spontaneous play was recorded at 12 weeks of age in calves that stayed with mothers for the first 4 postpartum days. However, this evidence was weak, as other findings of the current study do not support it. Under natural conditions, calves spend first 2-5 days as “hiders” lying in vegetation, while their mother is grazing a few meters away and comes to the calf just for nursing. (Vitale et al., 1986) The calves start to associate with other peers just around the age of 2 weeks after birth (Le Neindre and Sourd, 1984). Calves in our experiment were housed with their mothers just 4 days after birth, which overlaps with the hider period. It remains an open question whether a longer postnatal cohabitation with the mother would have a stronger influence on later calf playfulness. Even when the play behaviour of calves remaining with their mothers and calves separated immediately after birth were compared at 90 days of age, the differences were complex, with the mother-reared calves displaying more social play but less locomotor play (Wagner et al., 2013).

It is possible that the effect on play of staying with the mother for a few days is modified by subsequent rearing conditions, as we found a significant effect of group housing on play behaviour of calves. Calves housed in groups played significantly more than calves housed individually, which is in agreement with other studies (Jensen et al., 1998, Babu et al., 2004, Tapkı et al., 2006). The results indicate that the most common housing system for dairy calves, the small individual pen, reduces the natural expression of play behaviour. This could be either due to the absence of companions, or due to the lack of space available, as studies show that space availability plays a major role (Jensen et al., 1998, Jensen and Kyhn, 2000, Mintline et al., 2013). Other factors may undoubtedly also enhance play levels, such as feeding sufficient amount of milk (Krachun et al., 2010, Duve et al., 2012, Jensen et al., 2015).

In addition, in the 15-minute open-field tests, when single-housed calves were placed in a new pen with 3 unfamiliar calves, upon the brief encounter with an unfamiliar calf and at 8 weeks, the play levels of single-housed calves surpassed calves housed in groups. These differences demonstrate a powerful rebound effect (Dawkins, 1988) in play behaviour when calves housed in individual pens are exposed to larger space and companions. The increase in play activity can be explained by a build-up of inner motivation to play during deprivation, or it may be a response to novelty (i.e., the first contact with a social partner and with a new pen) (Mintline et al., 2012). The fact that in home pens the play activity of individually housed calves was lower, indicates that they might have been play-deprived.

The study also revealed a significant effect of the social housing of calves on their growth. The calves that stayed with their mothers for 4 days of postpartum grew faster than the calves separated from their mothers within 24 hours after birth, and they were still heavier at the end of the first week. But the difference in weight between calves with mother and without mother in the first 4 days of postpartum disappeared by week 2. It is well documented that calves allowed to stay with their dams grow much faster (Metz, 1987, Krohn et al., 1999, Flower and Weary, 2001). This effect is probably due to higher colostrum and milk consumption (Krohn et al., 1999). The enhanced growth in calves kept with their mothers can occur especially if the separated calves are fed a low milk allowance, as was the case in our study, where calves were fed only 4 litres of milk a day after separation, meaning that following separation, the calves' feeding level probably halved. Such a sudden drop in milk intake may negate the potential long-term positive effects of mother-rearing. Calves with ad libitum access to the milk drink between 8 and 10 litres of milk per day (Jasper and Weary, 2002) and most of the farmers currently provide daily 10 – 15% of body weight in milk to their calves (Staněk et al., 2014). Four litres of milk per day is probably undercutting the growth potential of the previously suckled calves.

The calves housed in groups weighed about 15% more than single housed calves whether they had been previously housed with their mother or not. Calves in group housing grew better despite all calves were fed the same, albeit low, amount of milk. Also, it is improbable that faster growth was due to lower energy expenditure for physical activity because calves in group housing actually played more than single housed calves and higher play levels are indicative of higher total locomotion (Rushen and de Passillé, 2012). Possibly, social facilitation (Zajonc, 1965) or social learning (De Paula Vieira et al., 2012, Gaillard et al., 2014) may increase solid food intake in grouped calves, as has been reported in dairy cows (Grant and Albright, 2001). Grouped (Phillips, 2004, Hepola et al., 2006, Lv et al., 2021) and paired (De Paula

Vieira et al., 2010; Jensen et al., 2015) calves, respectively, were consuming more solid food and started to ruminate earlier (Babu et al., 2004, Hepola et al., 2006) than individually housed calves, which can be the reason why socially housed calves had higher body weight or weight gain. On the other hand, with the increasing number of calves in the group, the risk of food competition (von Keyserlingk et al., 2004) and of disease pathogens contraction increases as well (Svensson and Liberg, 2006, Lv et al., 2021). This can lower the positive effects of group housing of calves and it is necessary to consider these factors while bringing social housing of calves into practice.

Potentially, better social skills gained through enhanced play behaviour and better growth in the early ontogeny period could translate in subsequent better health and/or higher performance, which Study II investigated. Within the results of Study II we did not find any significant influence of the stay of the calf with its mother during the first 4 days of life and/or the presence of companions provided by the group housing on the longevity or production during the first lactation, age at first successful conception, sum of the milk yield during first lactation, the average speed of milking during first lactation, body weight loss during the first three weeks of lactation or the change in locomotion around the group changes. The results of this study disagree with studies of Broucek et al. (2006) and Broucek et al. (2005), which demonstrated that calves kept with their mothers for one week after birth (Broucek et al., 2006) and calves housed in group of 13 calves with maximum 3 nursing cows (Broucek et al. (2005), had better milk performance during first lactation. The possible explanation why the results of both studies differ is similar to the explanations in Study I. The positive effect of social housing of calves on their subsequent milk production in the study of Broucek et al. (2005) could be boosted by the presence of foster cows and access to a higher amount of milk (6 litres vs 4 litres), given more times per day in different ways (access to a teat ad libitum vs bucket feeding two times per day). In addition, the stay with the mother in the current study lasted just 4 days which was probably too short for showing any influence on the studied variables that were measured at least 1 year later. Cattle are considered a hider species with calves staying individually hidden in vegetation and awaiting the mother's appearance, which means that during the first five days of its life the calf's first and only social partner is usually the mother and with her help the calf is learning its first social skills (Vitale et al., 1986). The calf starts to follow its mother to the herd just after this period

(Le Neindre and Sourd, 1984) and spends another one week mainly in her proximity (Grøndahl et al., 2007). When a heifer is raised in a company of her dam, her physical (Metz, 1987, Krohn et al., 1999, Flower and Weary, 2001, Flower and Weary, 2003) and psychological (Weary and Chua, 2000, Flower and Weary, 2001, Buchli et al., 2017) development is positively affected, thus enhancing her welfare. Better social skills may help the animal later in life in social group organization and in interactions with other animals (Broom and Leaver, 1978, Le Neindre and Sourd, 1984, Wagner et al., 2012). However, the 4 days might not be enough to form and preserve these skills. Another question is whether staying with the mother for 4 days does not stress the cow and the calf more by separation and breaking the freshly established mother-young bond. Therefore, the 4 days that calves spend with their mothers can bring only a time-limited advantage in milk intake and is not long enough to achieve significant long-lasting effects on the reproductive and lactation performance of observed animals. A calf might need to spend longer time with its Mum for the long-term effect to show.

While we did not find any effects of early group housing on later female dairy cattle traits, we cannot conclude that such effects do not exist. This study was focused on the first lactation only, with the exception of longevity and was also limited in the number of measured parameters. In addition, just one indicator of cows' reaction to group change (locomotion) was collected, which does not give the full picture of social reactions and social behaviour in the group. Also in our experiment, two breeds of cattle were used and therefore the breed and management could have a significant effect on locomotion and some production traits. Although we did not find any significant effects of the presence of the mother in the first 4 days after birth, nor did we observe an effect of group housing on activity after moving the animals to new groups and production traits, we found a significant influence of breed. Our results show significant increase of locomotion after the cows were moved between groups during lactation. Free range cows spend usually their entire life in the herd where they were born (Lazo, 1994). When two different herds meet, or when a new cow is introduced to the herd, the animals employ agonistic behaviour to establish a hierarchy (Lamb, 1975, Orihuela and Galina, 1997). Part of a monitored enhanced locomotion was probably similarly connected with agonistic behaviour and establishing social hierarchy, especially because the first-lactation cows met many cows in the new group for the first time in their life. In the results of our study, Holstein cows were less active after the group change than the Czech Fleckvieh cows, which can be linked to another of our findings, where Holstein cows lost significantly more weight during the first 21 days of lactation than Czech Fleckvieh cows. Holstein primiparous cows were found to lose more weight than Czech Fleckvieh primiparas during the first weeks of lactation also in a larger sample studied by Rehak et al. (2012). A larger body mass loss indicates a stronger squeeze in available energy in the Holsteins which could reduce their motivation for locomotor activity.

For data collection in Study II, Precision dairy monitoring technologies were used. These technologies use automated, mechanized technologies for refinement of dairy management processes and procedures, or information collection (Bewley, 2016). Many precision dairy monitoring technologies are commercially available and are being used in research and on farms (Borchers et al., 2017). But the use of commercially available precision dairy monitoring technologies in data collection for research purposes is still in the beginning and deserves special attention, since with the use of Precision dairy monitoring technologies it is possible to easily acquire a significant amount of daily data about individual animals (Rutten et al., 2013). It took over four years to collect all necessary data from 40 experimental calves (later cows) and in the end unique data was acquired. The dataset shows association of different types of housing during early ontogeny in calves and milk production, body weight (in early ontogeny and in first lactation) and activity in dairy cows during their first lactation in two different breeds. The datasets were published separately because we wanted to document that quality data are possible to provide by commonly used commercial precision dairy monitoring system. In addition, these data can be beneficiary for researchers and other stakeholders working in cattle welfare improvement, for the analysis or metanalysis of a cow's production with connection to early ontogeny rearing and welfare, for the assessment of welfare indicators in dairy systems and dairy cattle welfare improvement.

Looking for alternative rearing of dairy calves, one which corresponds with the natural social environment of calves, gave people the idea to house dairy calves together with their mothers (cow-calf system). In the possible application of housing the lactating cows together with their calves in dairy practices, the strongest concern is the significant response of both the cow and the calf to a later mutual separation (Johnsen et al., 2016) as calves and cows experience strong stress reaction while they are separated (Ungerfeld et al., 2009, Lynch et al., 2010b, Lynch et al., 2010a, Ungerfeld et al., 2011, Johnsen et al., 2016), which can suppress the positive effect of dam-rearing of calves as was suggested also in Study I (Valníčková et al., 2015). Extensively reared beef cattle are the perfect model for understanding the factors affecting the stress response to mutual separation of the cow and the calf and findings of this study can be used in bringing dairy cow-calf systems into the practice. In Study III we found the strongest factor affecting the cow reaction was the age of the calf, where mothers of younger calves tried harder to re-establish contact with their calves, both through more frequent vocalizations and through enhanced locomotion. A study of Pérez-Torres et al. (2016) also found that cows with younger calves vocalized more when separated from their progeny, although their study was made at a much earlier age (either 25 or 45 days). On the other hand, if the progeny is more independent or if the maternal resources are limited, the mother should limit the care for the current offspring and thus spare resources for future reproduction. It is well documented that the mother–young bond in cattle and related artiodactyls gradually weakens as the calf gets older, as reflected, for example, in the average duration of suckling bouts (Lidfors et al., 1994) or in the cow–calf physical proximity (Veissier et al., 1990). Therefore, separating calves early stresses the cow, but timing of the weaning of the calf from the mother may have an effect on economic stability of the farm and earlier weaning of calves from cows is wanted. Nevertheless, our results also show that the cow's reaction peaks within the first day, and therefore, the welfare problem may not be long lasting. Calves in Study III were weaned between 5 and 9 months of age and surprisingly the age at weaning did not affect vocalization rates of the calves and the amount of movement was positively related to age. These findings are contrary to our hypothesis that younger calves will react more because they would benefit more from the continuation of maternal care. This hypothesis was supported also by Lambertz et al. (2015), who showed that younger calves weaned at 6 months of age vocalized more than calves weaned at 8 months. We do not have a sufficient explanation of the nonsignificant result on vocalization in the current study. As for the unexpected positive relationship between age and movement, one possibility is that movement is in fact not a suitable measure of post-weaning stress in calves.

Furthermore, we found that male calves cope with weaning distress better than females; females vocalized more than twice as much as males, supporting our prediction that heifers have more to lose from weaning than bull calves. This result is in agreement with another study where female calves weaned at 6 or 8 months vocalized more than bull calves during the first day after separation (Lambertz et al., 2015). It has been also shown that until 6 months of age, heifer calves spent more time within 50 meters radius of their mothers than bull calves did (Lidfors and Jensen, 1988) and usually remain attached to their dam long after their weaning (Reinhardt and Reinhardt, 1981, Green et al., 1989, Veissier and Le Neindre, 1989, Veissier et al., 1990, Enríquez et al., 2011). This all corresponds with the natural conditions, where heifers stay in the same herd for the whole life unlike bulls, which eventually leave the herd (Lazo, 1994). This finding may support the practice that just bull calves are removed from their mother earlier, since mostly dairy bull calves are sold at a young age, and also to prevent premature breeding. On the other hand, a study conducted by Hickey et al. (2003) showed that the bull calves dealt worse with abrupt weaning than heifers. But Hickey et al. (2003) observed only noradrenaline in the blood of weaned calves and performed no behavioural observation during the weaning process. In the light of this, there might be a difference between physiological and behavioural reactions of calves to weaning.

6 Conclusions

The articles presented in this thesis showed that housing of calves in groups of 4 between the first week and the eighth week of age increased play rates and enhanced body weight compared with single housed calves. When exposed to a larger pen or a companion, the single housed calves rebounded into intensive play behaviour, indicating that they were play deprived in the single pens(home pens).. Staying with the mother for the first 4 days gave calves a weight gain advantage that persisted until the beginning of the second week of age, but did not increase play behaviour later on, except for a questionable increase at week 12. Therefore social housing of calves during the milk feeding period has a positive effect on their behaviour and weight gain and in the dairy calves rearing practice it can significantly improve the welfare of calves.

Despite the significant short-term effect of social housing of calves, no effect of presence of companions, nor the short stay with the mother during the period of early ontogeny persisted until adulthood, and there were no differences found in longevity, production traits during the first lactation and activity after change of social environment. The results indicate that neither provision of maternal care for the first 4 days nor group housing for the duration of milk feeding period bring any advantage or disadvantage for the first lactation performance in dairy cattle and farmers do not need to be concerned about weaker production or increased mortality of cows originating from social housing in the period of early ontogeny. Studies I and II show that group housing improves the performance and welfare of dairy calves and from the point of the examined long-term effects, social housing of dairy calves is on par with the traditional individual housing.

In addition, we documented a new method of data collecting with the use of commercial Precision dairy monitoring systems and provided high quality data, which can be used for further analyses of the influence of parameters from early ontogeny on cow performance, especially during the first lactation. This information can be useful for researchers and other stakeholders investigating the influence of early ontogenetic social environment on the dairy cattle performance and welfare.

with regard to the question of bringing cow-calf systems into the dairy practice, the biggest concern is stress during the weaning and the separation of the calf from the cow. We found the strongest factor affecting the cow's reaction was the age of the calf. To separate calves early stresses the cow, but timing of the weaning of the calf from the mother may have effect on the economic stability of the farm and earlier weaning of calves from cows is wanted. This study shows that cow and calf reaction to abrupt weaning, as expressed in vocalizations and movement, is affected by the individual condition of the mother and the offspring. The cow's reactions were reduced if the calf was older and if the cow was concurrently pregnant. The calf's reactions were stronger in females compared with males. For both cows and calves, the reactions were stronger if the calf grew faster before weaning. These results document that the ability to adaptively adjust mother–young interactions has been preserved in domesticated cattle. Nevertheless, our results also show that the cow reaction peaks within the first day, and therefore, the welfare problem may not be long lasting. Furthermore, we found that male calves cope with weaning distress better than females, which supports the practice that just bull calves are removed from the herd. These findings could be also taken into account in the current efforts to make weaning less stressful in practical husbandry, and as we observed cows and calves who were separated in ages form 5 to 9 months and we still observed strong reactions to separation in both the cow and the calves, we might say further investigation of various methods of cow-calf dairy systems and more research in the question of socialization of calves and level of stress and animal welfare during mutual separation of cows and calves is needed.

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