

Signs of hunger in dairy calves indicate suboptimal periods in two weaning methods

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ABSTRACT

In order to promote rumen development by stimulating concentrate intake, dairy calves are usually fed low amounts of milk, however this may result in prolonged hunger. Furthermore, calves are often weaned off milk without considering individual capacity to feed on solid food. We investigated the effects of two feeding regimes differing in milk allowance and in how milk was reduced on signs of hunger and concentrate intake. After birth, 17 calves were housed individually for two weeks. Then, calves were moved to a group pen and nine calves were assigned to the weaning method “individual weaning” (restricted milk amount before gradual weaning, gradual weaning off milk dependent on concentrate intake), the other eight calves to “ad libitum” (high amount of milk before gradual weaning, gradual weaning off milk on a fixed schedule). Average weaning age did not differ between treatments but varied greatly between individual calves. Before gradual weaning, individually weaned calves

engaged in more unrewarded visits to the milk feeder than ad libitum calves. During gradual weaning, the number of unrewarded visits of individually weaned calves decreased, while it increased in ad libitum calves. During unrewarded visits, the number of contacts with the teat increased during gradual weaning in both weaning treatments. Whereas the increase was only marginal in individually weaned calves, it was considerable in ad libitum calves. Concentrate consumption increased in both groups from before to during gradual weaning. However, both before and during gradual weaning, individually weaned calves consumed a higher proportion of their daily concentrate allowance. On average, individually weaned calves consumed less milk and more concentrate over the course of the weaning process. The findings regarding unrewarded visits to the feeder, however, indicate that calves in both treatments showed signs of prolonged hunger before and/or during gradual weaning and stress the importance of further improving weaning treatments.

Calf, concentrate consumption, milk allowance, behavior

INTRODUCTION

Newly born calves are pre-ruminants, i.e. their digestive system works similar to that of monogastric animals, and they rely on milk that is digested in the abomasum. Over time, the digestive system matures and calves become fully functional ruminants (Heinrichs and Lesmeister, 2005). To promote the intake of solid feed and thereby accelerate the weaning process, calves are commonly fed low milk rations. During the first rearing period, daily milk rations represent on average 10-20% of calves' body weight (approximately 6 l/d), which is about half the amount calves drink when given ad libitum access to milk/milk replacer (Appleby et al., 2001) or when calves have temporary access to their mothers to suckle (de Passillé et al., 2008). Particularly during the first weeks of life, when rumen, reticulum and omasum are not yet (fully) functional, calves cannot compensate low milk rations by a higher

intake of solid feed (Jasper and Weary, 2002). Given all of the above, restrictive milk feeding regimes can lead to hunger in calves (de Paula Vieira et al., 2008). Usually, milk allowance is gradually reduced in a second rearing period and calves are eventually completely weaned off milk at an age of about 9-12 weeks. In this second period, milk rations are reduced often irrespective of whether calves' concentrate and roughage intake meets their nutritional requirements. This gradual weaning can be another cause of hunger in calves (Roth et al., 2008; de Passillé and Rushen, 2016). In automatic feeding systems, high numbers of unrewarded visits to the milk feeder are indicative of a high motivation for milk (de Passillé et al., 2011) and have been used as an indicator of hunger in dairy calves (Jensen and Holm, 2003; de Paula Vieira et al., 2008; de Passillé and Rushen, 2016). Earlier studies found that restrictively fed calves also spent more time sucking the teat during rewarded visits after milk allowance had stopped than ad libitum fed calves (de Paula Vieira et al., 2008). Thus, it is plausible to assume that contacts with the teat reflect the attempts to get milk, i.e. are a proxy for the calves' intensity of motivation for milk.

In recent years, new weaning methods have been developed. One method greatly increases milk allowance in the first rearing period ("ad libitum") which can be expected to alleviate hunger. However, the subsequent gradual weaning process usually follows a fixed schedule by successively reducing milk allowance without considering the calves' capacity to consume concentrate and roughage. Another method is the concentrate-dependent weaning ("individual weaning") in which reduction of milk allowance is determined by each calf's individual concentrate consumption (Roth et al., 2008; Roth et al., 2009; de Passillé and Rushen, 2016; Benetton et al., 2019). This method aims at meeting the nutritional need of each individual calf thereby preventing hunger and negative effects on development and growth. However, since the start of reducing the milk allowance depends on the consumption of a defined minimum amount of concentrate, calves usually are offered low milk rations in the first rearing period to initiate concentrate consumption (Roth et al., 2008). Consequently, both of

the described methods improve only one of the two periods: either the period *before* gradual weaning (“ad libitum”) or the second period *during* gradual weaning (“individual weaning”). For each weaning method, calves might thus show signs of prolonged hunger during the respective non-improved period, and this might be additionally affected by the early milk feeding regime during the first weeks of life.

In the present study, we used two indicators of prolonged hunger (unrewarded visits to the milk feeder and teat contacts during these unrewarded visits) to investigate the periods (“before gradual weaning” and “during gradual weaning”) of the “individual weaning” and the “ad libitum” weaning method. Indications of hunger were complemented by the analysis of concentrate consumption. Consequently, our aim was to investigate the effects of the two weaning methods used in practice on signs of hunger and concentrate to identify periods that might pose a risk to the calves’ welfare.

MATERIAL AND METHODS

Ethical approval to conduct the study was obtained from the Cantonal Veterinary Office, (Frauenfeld, Thurgau, Switzerland, Approval No. TG05/13). The experiment was conducted between Mai 2013 and February 2014 at the Agroscope research farm (Tänikon, Switzerland).

To reduce the variability due to sex, only the seventeen female calves that were born in that period were recruited into the study. After birth, calves were housed individually for two weeks in igloos (2.4 m² straw bedded area and a 1.1 m² outdoor run) with visual and acoustic contact to conspecifics. Calves were assigned to one of two early milk feeding regimes (Figure 1). Ten calves were fed 6 l/d of cows’ milk (= “low”) and seven calves had access to a maximum of 13 l/d of cows’ milk (= “high”). In week three postpartum, calves were moved to a straw bedded group pen (24 m²) with a permanent outdoor run (11 m²). Since all calves born on the farm were kept in this group pen from week 3 until weaning was completed, the

number of calves within the group pen varied (max. 12 calves in the group pen at the same time). At the time of moving, calves (mean age 15 days, range 8-21 days) were alternately assigned to one of two weaning treatments. Thus, calves of both early milk feeding regimes were assigned equally to either of the two weaning treatments.

The two weaning treatments were “individual weaning” (n = 9) during gradual weaning and “ad libitum” (n = 8) before gradual weaning (Figure 1). In the group pen, data collection started after the second week of life and was divided into the two periods “before” and “during” gradual weaning. Calves had free access to an automated milk feeder and an automated concentrate feeder (both FA Foerster-Technik GmbH, Engen, Germany). A chip in the neckband allowed each calf to be individually recognized by the two feeders, and calves were fed an individually defined daily amount of milk replacer (50:50 mixture of milk replacer and whole milk (19 MJ ME/kg TS, milk replacer: UFA 207 plus) and concentrate (UFA 116, 12.2 MJ ME/ kg TS). The amount of milk replacer and concentrate consumed in each visit as well as the number of visits to the feeders were recorded automatically.

Additionally, the milk feeder recorded the number of contacts made with the teat during each visit. Total milk and concentrate consumption from being moved to the group pen to completed weaning was determined for both the ad libitum weaned and individually weaned calves by adding the daily amount each calf consumed during that period. The milk feeder was equipped with a stall protecting the calf’s body and an automatic gate at the back of the stall ensured that other calves could not displace calves with milk allowance during their visits at the milk feeder. The concentrate feeder included a feeding stand that covered the front half of the calves’ body but could not fully prevent them from being displaced by other calves.

Individually weaned calves had access to 6 l/d of milk before the gradual weaning started. As soon as calves consumed ≥ 700 g/d of concentrate on each of four consecutive days, gradual

weaning started. The correlation between milk amount and concentrate amount during gradual weaning was inverse, and daily milk allowance was based on the average amount of concentrate consumed over the last 4 days (Roth et al., 2008). Milk amount was reduced by 1 l for every increase in concentrate consumption of 250 g. In the case of reduced concentrate consumption, the amount of milk remained constant and was not increased again. Milk allowance ceased completely when calves consumed 2000 g/d of concentrate on each of four consecutive days.

Ad libitum calves received a maximum of 13 l/d of milk before gradual weaning. At the same time, they had access to a maximum of 750 g concentrate per day. Twenty-eight days after being moved to the group pen, gradual weaning started: first, milk allowance was reduced to 8 l/d during seven days, then it was reduced until weaning was completed after another 42 days. During the 49 days of gradual weaning, the amount of concentrate allowance was increased for the ad libitum calves from 1000 g/d to 1500 g/d during 21 days and to 2000 g/d during the remaining 28 days. Calves in both weaning treatments had ad libitum access to hay and water.

STATISTICAL ANALYSIS

To evaluate the outcome variables, we used generalized linear mixed models (to adequately reflect dependencies in the experimental design, i.e. repeated measures, Table 1). Statistical analysis was performed in R (version 3.3.1, R Development Core Team, 2020) using `glms`, `lme` (package `nlme`; Pinheiro et al., 2016) and `glmer` (package `lme4`; Bates et al., 2015).

Due to the small sample size, we restricted the maximum models to selected interactions between fixed effects that were of a-priori interest and did not include all possible interactions (Table 1). For all analyses described, days during which calves were ill (= i.e. received veterinary treatment; six animals in total: two individually weaned calves and four ad libitum calves) were excluded from analysis (excluded days: range: 5-23 days, median: 16 days). For

each model, p-values of the individual fixed effects were calculated by comparing the model with and without each factor using likelihood-ratio tests (glmer method) or pseudo-F-tests (gls and lme methods). Model assumptions were verified using graphical analysis of residuals focusing on normality of errors and random effects as well as homoscedasticity of the errors. For age at the time of completed weaning, we used a one-sample t-test to assess if weaning age of individually weaned calves differed from the planned weaning age of ad libitum weaned calves.

RESULTS

The **age at the time of completed weaning** of individually weaned calves did not vary to that of ad libitum weaned calves (Table 1). As expected, however, age at the time of completed weaning varied greatly between individually weaned calves (56-113 days) compared to ad libitum weaned calves (86-93 days).

Before gradual weaning started, individually weaned calves engaged in more **unrewarded visits to the milk feeder per day** than ad libitum weaned calves. During gradual weaning, however, the number of unrewarded visits of individually weaned calves decreased, while it increased in ad libitum weaned calves (Table 1, Figure 2a). However, the number of unrewarded visits of individually weaned calves during gradual weaning remained higher than the low level of unrewarded visits of ad libitum calves before the start of gradual weaning.

During gradual weaning, the **number of contacts with the teat during each unrewarded visit** was higher compared to the period before gradual weaning. The increase was more pronounced in the ad libitum weaned calves than in the gradual weaned calves, though statistical support for this difference in slope was only marginal (Table 1, Figure 2b).

In both weaning treatments, the **proportion of concentrate consumed daily** in relation to a maximally available amount of 2000 g/day increased from before the start of gradual weaning

to during gradual weaning. However, the increase was higher in individually weaned calves both before and during gradual weaning (Table 1, Figure 2c).

The early milk feeding regime had no detectable effect on unrewarded visits to the milk feeder per day, number of contacts with the teat during each unrewarded visit, and proportion of concentrate consumed daily (Table 1). In the period from being moved to the group pen to completed weaning, individually weaned calves consumed on average 63 l less milk (**total amount of milk**) and 17 kg more concentrate (**total amount of concentrate**) than ad-libitum weaned calves, though this difference could only marginally be supported by the statistics due to the large between-calf variability (Table 1).

DISCUSSION

We found clear effects of the weaning methods on the **number of unrewarded visits to the milk feeder per day**, which was higher in individually weaned compared to ad libitum weaned calves before gradual weaning. This is in accordance with a study by Rosenberger et al. (2016) and Korst et al. (2017) and indicates that with low milk allowance calves were exhibiting milk seeking behavior and were therefore likely hungry.

Similar to Roth et al. (2008), we found a decrease in the number of unrewarded visits in individually weaned calves during the period of gradual weaning. However, this decrease was not as marked as expected. This may indicate that the criterion of when to start the decrease in milk allowance (700 g/d concentrate intake on four consecutive days) as well as the proportional decrease of milk allowance given the increased concentrate consumption were suboptimal, e.g. reduction starts too early (calves do not consume enough concentrate yet), is completed too fast (milk allowance is reduced in too big steps), or is not suitable for all calves. The importance of how milk allowance should be reduced is also reflected in a study by de Passillé and Rushen (2012) who found that the duration of the weaning process is affected by both the amount of concentrate that needs to be consumed to start and to

complete the weaning process. Further, Bittar et al. (2020) who compared abrupt and gradual weaning, found that average daily gain, weight and overall growth was effected by concentrate intake at the start of the weaning process but not the following weaning treatment (abrupt vs. gradual). However, when comparing studies investigating different weaning treatments it has to be noted that they often vary in terms of the criteria that determine when milk allowance is reduced or ceased, i.e. age, or amount of concentrate consumed over how many days. It is worth noting that in both our weaning treatments some calves performed more than 30 unrewarded visits per day. Calves in the ad libitum weaning treatment showed a low number of unrewarded visits before gradual weaning, which supports the assumption that offering calves a high milk allowance prevents prolonged hunger. Similar to the number of unrewarded visits, **the number of contacts with the teat** can be extremely high, with some calves showing more than 50 contacts per unrewarded visit (please note: whiskers in Figure 2b cut off at 40 to improve visibility). Interestingly, a high number of contacts occurred in both weaning treatments. Overall, however, the number increased specifically during the period of gradual weaning in ad libitum weaned calves. Consequently, this indicator might be suitable to infer motivation for milk in calves.

In both weaning treatments, the **proportion of consumed concentrate** was higher during gradual weaning compared to before gradual weaning, indicating that in both weaning treatments the maturation of the digestive system progressed. However, in both periods (before and during gradual weaning), individually weaned calves consumed a higher proportion of concentrate than ad libitum weaned calves, i.e. it can be assumed that the development was faster in individually weaned calves. This would be in accordance with findings of Roth et al. (2008) where individually weaned calves seemed to show a more steadily increasing weight gain compared to conventionally weaned calves.

Both the ad libitum and the individual weaning treatment are examples of improved weaning treatments. Yet, calves in both treatments showed signs of prolonged hunger. In both weaning treatments the majority of unrewarded visits occurred during the period that had not been improved (individual weaning: before gradual weaning, ad libitum: during gradual weaning). Therefore, the results of the present study stress the importance of refining weaning treatments to prevent prolonged hunger in calves. The individual progress in the development into a ruminant seems to be very important here as we found that **age at the time of completed weaning** was variable in individually weaned calves in accordance with de Passillé and Rushen (2016) and Roth et al. (2008; 2009). The issues of how to promote concentrate consumption when offering higher milk rations, and which amount of concentrate will ideally be used to initiate gradual weaning as well as how to link milk and concentrate consumption during the weaning process need to be addressed in future experiments.

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Table 1. Estimated effects as well as test statistics (one-sample t Test, pseudo-F-test and F-values for models with normally distributed errors and likelihood-ratio test and χ^2 – values for models based on Poisson distribution) and p-values of the full model and all outcome variables.

Outcome variable	Method	Error distribution	Random factors	Explanatory variables	Test results	Estimated differences
Age at weaning ¹	One-sample t Test	Normal	-	Individually weaned calves only	$t_8 = -0.32, p = 0.76$	0.97 [0.79, 1.16]
Total milk consumption	gls	Normal	-	Weaning treatment ³	$F_{1,15} = 4.34, p = 0.055$	individual weaning: 260 l [209, 311] ad libitum: 333 l [279, 387]
Total concentrate consumption	gls	Normal	-	Weaning treatment ³	$F_{1,15} = 2.43, p = 0.14$	individual weaning: 67.6 kg [50.8, 84.3] ad libitum 49.7 kg [31.9, 67.5]
Number of unrewarded visits to the milk feeder per day	glmer	Poisson	Period nested in calf identity	All Weaning treatment ³ Period ⁴ Weaning treatment \times Period Early milk feeding regime ⁵	$\chi^2_4 = 61.72, p < 0.0001$ $\chi^2_1 = 31.61, p < 0.0001$ $\chi^2_1 = 19.72, p < 0.0001$ $\chi^2_1 = 33.19, p < 0.0001$ $\chi^2_1 = 0.48, p = 0.49$	– } Fig. 2a low: 6.2 [5.2, 7.1], high: 5.8 [4.9, 6.8]
Number of contacts with the teat during each unrewarded visit	glmer	Poisson	Date nested in period nested in calf identity	All Weaning treatment ³ Period ⁴ Weaning treatment \times Period Early milk feeding regime ⁵	$\chi^2_4 = 11.04, p = 0.03$ $\chi^2_1 = 0.01, p = 0.92$ $\chi^2_1 = 7.41, p = 0.006$ $\chi^2_1 = 3.62, p = 0.057$ $\chi^2_1 = 1.87, p = 0.17$	– } Fig. 2b low: 5.8 [4.6, 7.3], high: 7.4 [5.7, 9.7]
Proportion of daily concentrate consumption ² (logit transformed)	lme	Normal	Period nested in calf identity	All Weaning treatment ³ Period ⁴ Weaning treatment \times Period Early milk feeding regime ⁵	$\chi^2_4 = 65.04, p < 0.0001$ $F_{1,14} = 49.85, p < 0.0001$ $F_{1,14} = 160.73, p < 0.0001$ $F_{1,14} = 7.12, p = 0.012$ $F_{1,14} = 0.03, p = 0.86$	– } Fig. 2c low: 41 % [30, 53], high: 43 % [29, 57]

¹ Difference in age at the time of completed weaning (quotient of age in days at the time of completed weaning of individually weaned calves divided by 86 (= expected duration of weaning of calves in ad libitum treatment)). Quotient = 1: individually weaned calves and ad libitum calves have same age at weaning; <1: individually weaned calves are younger at weaning than ad libitum calves; >1 = individually weaned calves are older at weaning than ad libitum calves.

² In relation to the max. concentrate consumption = 2000 g/d. Note that concentrate allowance was lower than 2000 g/d before gradual weaning in ad libitum weaned calves, but the maximum allowance in that period was not reached by any calf. Using the proportion of the daily consumed amount of concentrate relative to a maximum amount of 2000 g/d did, therefore, not skew the data but rather led to comparable data between calves of the two weaning methods throughout the different phases.

³ Factor with 2 levels: individual weaning, ad libitum

⁴ Factor with 2 levels: before gradual weaning, during gradual weaning

⁵ Factor with 2 levels: low, high

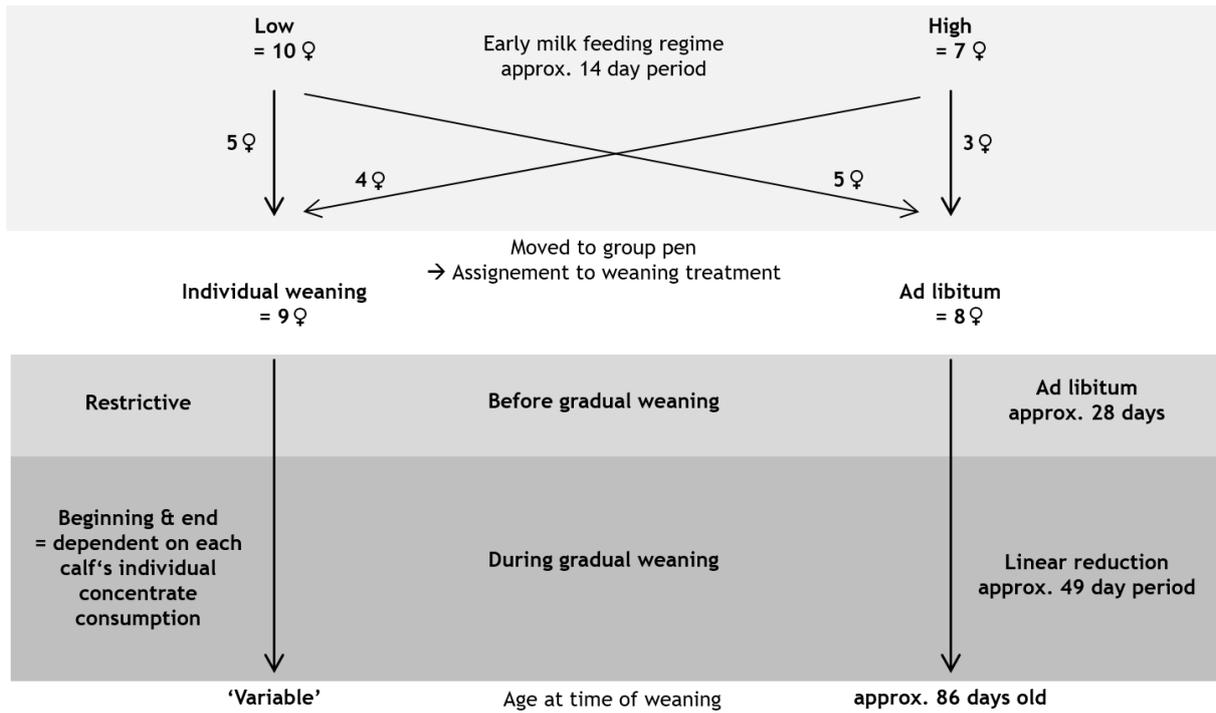


Figure 1: Schematic presentation of the course of the experimental set up.

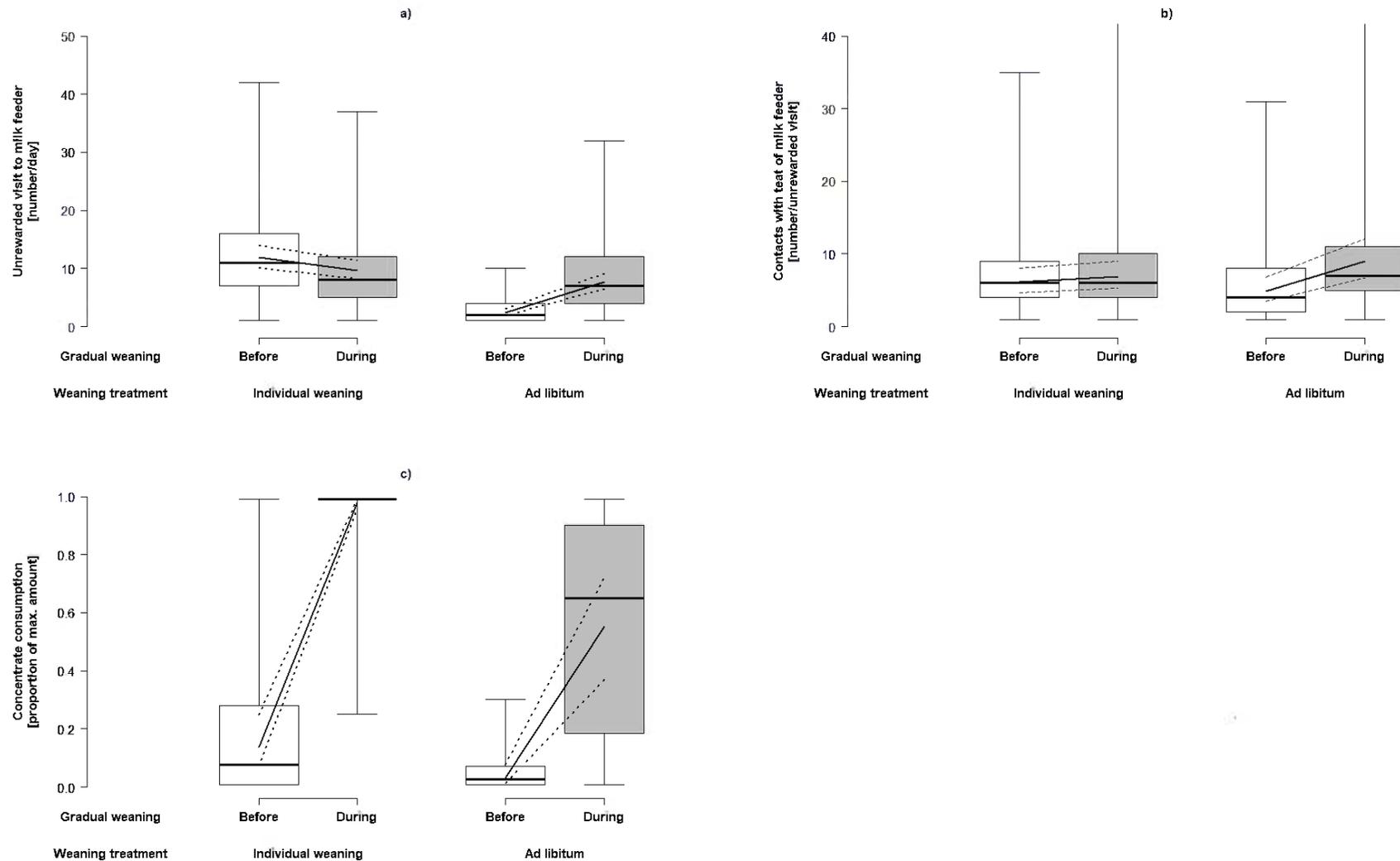


Figure 2: Number of unrewarded visits to the milk feeder per day (a), number of contacts with the teat during each unrewarded visit (b), and proportion of concentrate consumed daily in relation to maximally available amount of concentrate (c) in dependence of weaning period (“before” and “during” gradual weaning) and weaning method (“individual weaning” and “ad libitum”). Box-and-whiskers plot: boxes = 1st and 3rd quartile, thick line = median, whiskers = range from minimum to maximum value. Solid lines = model estimates, dotted lines = 95% confidence intervals.

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