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Effect of Choice Feeding in the Pre-weaning Period on the Growth Performance of Calves during the Pre- and Post-weaning Periods

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Authors' contributions

This work was carried out in collaboration between all authors. Author MG designed the study, performed the statistical analysis, wrote the protocol and the first draft of the manuscript. Author MWH carried out experiment with calves. Author SG managed the literature searches and wrote the manuscript the study. All authors read and approved the final manuscript.

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ABSTRACT

The aim of this study was to investigate the effects of choice feeding in the pre-weaning period on the growth performance of calves during the pre- and post-weaning period. It is possible that high Crude protein (CP) intake during the pre-weaning period may improve post-weaning performance of calves. Currently, there is insufficient data available on the effect of pre-weaning feeding method on post-weaning performance of calves; therefore the aim of this study was to examine the effect of choice feeding on growth performance of calves during the pre and post-weaning period.

Results: Twenty eight male and 28 female Holstein calves were assigned to two different feeding systems. After weaning calves were fed with the same Total Mixed Ration (TMR) (50% calf grower + 50% alfalfa hay). Prior to weaning, choice-fed calves preferred the diet containing lower alfalfa and barley, and higher wheat bran and soybean meal ($P<0.01$). Choice feeding increased nutrient intake (protein and fiber) and daily weight gain ($P < 0.05$). The Metabolisable Energy (ME), Crude Protein (CP), Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) contents of the diets selected by choice calves were 2.60 Mcal/kg, 29.24%, 27.18% and 12.01%, respectively. The TMR

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contained 2.23 Mcal/kg ME, 17.94% CP, 24.99% NDF and 11.85% ADF. Results show that calves choose their diet may meet their nutritional requirement and gain more weight.
Conclusions: In this study choice fed calves had higher daily weight gain during the pre-weaning, but not post-weaning, period. Furthermore, high preference for protein may have the long term effects on performance of young calves. It is therefore necessary to investigate the effect of early dietary preference of calves on their adult performance.

Keywords: Calf; choice feeding; diet preferences; weaning.

1. INTRODUCTION

Young animals fed kept with their dam are able to learn to select certain food types [1]. In intensive dairy production, calves are separated from their dam at an early age and may have limited visual contact with other calves or dams. This practice may be detrimental to the calves' ability to learn selection of adequate and appropriate feed to meet their nutrient requirements. Simitzis et al. [2] reported young animals have some degree of innate ability to choose and consume feed to meet their nutrient requirements, in addition to avoiding certain toxins and antinutritional factors in feeds (eg. tannins). Lambs and goats fed with ingredient separately, simultaneously and ad libitum (choice-feeding or cafeteria feeding) have been shown to be able to meet their nutrient requirements by selecting a diet corresponding to their physiological status and environmental conditions [3,4]. Choice-fed calves may be able to select a more nutritious diet than TMR fed calves receiving calf grower and hay in total mixed ration, in addition to maximizing their nutrient intake [5], and when given a free choice, young calves have been shown to preferentially consume milk replacer, followed by concentrate and roughage [6]. Individual variation in dietary choices has been observed; Gorgulu et al. [7] showed that choice-fed calves in pre-weaning period selected a diet containing higher crude protein (CP) (31 to 35%) than a standard starter protein level (18%) and that this preference was not changed after 2 weeks from weaning. Similar diet preferences were demonstrated by Miller – Cushon et al. [8] and Montoro and Bach [9], where choice-fed calves preferentially consumed soybean meal and/or full-fat soybean and consumed a diet containing high protein content (27-32%)compared to single base starter diet. Gorgulu et al. [7] also reported that pre-weaning weight gain of male calves was not affected by feeding methods (choice feeding vs TMR). Similarly, Hill et al. [10] indicated that there were no differences in the performance of calves fed starter feed containing 18.00% compared with 22.00% CP. Additionally, Sekine et al. [11] and Labussiere et al. [12] showed that performance and feed intake of calves was not affected by CP concentration of the starter feed, however, Drackley et al. [13] that calves fed with starter feed containing 22.00% CP were more efficient than those fed 18.00% CP.

As previously noted, choice-fed calves consume a high amount of protein, preferring protein-rich feed sources during the pre-weaning period as well as increasing feed intake [7]. It is possible that high CP intake during the pre-weaning period may improve post-weaning performance of calves. Currently, there is insufficient data available on the effect of pre-weaning feeding method on post-weaning performance of calves; therefore the aim of this study was to examine the effect of choice feeding on growth performance of calves during the pre and post-weaning period.

2. MATERIALS AND METHODS

The present study was approved by the Bioethics Committee of Çukur0va University (Protocol number:4/2013).

A total of 28 male and 28 female calves were allocated to 1 of 2 feeding methods (TMR-feeding and choice feeding with feed ingredients in the TMR) according to their birth weights. The initial mean body weights of the calves were 38.6 kg and 36.6 kg for the male and female calves, respectively. The calves in the TMR group received a diet containing concentrate and 10% ground alfalfa hay (1.5–2 cm chop length) ad libitum (Table 1). Calves in the choice-fed group received all feed ingredients used in the TMR on a free-choice basis, ad libitum. Feed ingredients used in the choice-fed groups, except alfalfa hay, were supplemented with limestone, salt and vitamin mineral premix with an amount of TMR. The TMR were formulated with barley, wheat bran, soybean meal, and alfalfa hay (Table 1). The ingredients and nutrient content of the TMR and the diets selected by choice-fed calves are shown in Table 1.

Table 1. Ingredients and nutrient contents of TMRs used during the pre and post-weaning periods (% as fed)

Ingredients	Pre-weaning TMR	Post-weaning TMR
Barley	52.29	
Wheat bran	17.28	
Soybean meal	17.73	
Limestone	1.71	
Salt	0.90	
Vitamin-mineral premix*	0.09	
Calf Grower***	0.00	50.00
Alfalfa hay	10.00	50.00
Total	100.00	
Nutrient composition		
Dry matter (DM, %)	90.77	89.15
Metabolisable Energy, (ME) Mcal/kg**	2.59	2.20
Crude Protein (CP), %	17.94	13.41
Acid detergent Fiber (ADF),%	11.85	27.67
Neutral Detergent Fiber (NDF), %	24.99	34.87
Ash, %	7.20	5.67
Ether extract, %	2.23	2.39

** 1 kg contains 8.000.000 IU vitamin A, 10.000.000 IU vitamin D3, 2.000 mg vitamin E, 30.000 mg Mn, 50.000 mg Zn, 50.000 mg Fe, 50.000 mg Cu, 10 mg Co, 150 mg I and 800 mg Se.*

***Concentrate ME content was calculated according to TSE (1991). Alfalfa hay ME content was calculated according to Schroeder (1994).*

**** Calf grower contained 16.7% CP and 2.66 Mcal ME/kg.*

The calves were housed in a semi-open barn, and each calf was kept in an individual pen (1.5 × 1.5 × 1.5 m). Conventionally, each calf was offered whole milk daily, in a plastic bucket; 2 L in the morning and 2 L in the evening, during an 8 week preweaning period. The chemical composition of the milk was; 12.2% Dry Matter (DM), 3.3% fat, 3.1% total protein, 2.6% casein, and 4.74% lactose. Post-weaning, all calves were fed with the same TMR containing 50% calf grower (16.7% CP, 2.66 Mcal ME/kg) and 50% alfalfa hay (1.5–2 cm chop length) mixed with wagon, ad libitum for 8 weeks, to evaluate the effect of pre-weaning feeding methods on post-weaning performance of the calves.

Live weight, live weight gain, and feed intake were monitored weekly. The feeds were offered ad libitum (refusals on the last day of the week were noted) and given to the animal by adding fresh feed or feed ingredients daily during the study period.

The chemical composition of the feeds was analyzed using AOAC [14] procedures. ADF and NDF analyses were based on the method of Van Soest et al. [15].

The study was performed according to a completely randomized design with a 2 (sex) x 2 (feeding method) factorial arrangement. Data were analyzed using a general linear model using SPSS [16]. Means were separated with a Duncan's Multiple Range Test. The difference between the diets selected by the calves in the choice feeding groups and the TMR in respect to ingredients and nutrient contents were assessed with a one-sample t-test and the differences between the diets selected by male and female were analyzed with a One Way ANOVA. Statistical significance was set at a value of $P < 0.05$.

3. RESULTS AND DISCUSSION

Prior to weaning, the choice-fed calves preferred the diet containing lower alfalfa (10.0% vs 5.80%; $P < 0.01$) and barley (52.3% vs 15.9%; $P < 0.01$), and higher wheat bran (17.3% vs 30.1%; $P < 0.01$) and SBM (17.7% vs 45.4%; $P < 0.01$). Sex did not affect diet preference ($P > 0.05$) (Table 2).

Choice feeding increasedprotein and fiber intakes and increased daily weight gain ($P < 0.05$). The ME, CP, NDF and ADF contents of the diets selected by calves were 2.60 Mcal/kg, 29.24%, 27.18% and 12.01% respectively, while TMR contained 2.23 Mcal/kg ME, 17.94%, 24.99% and 11.85%.

These results indicate that choice fed calves selected a high protein diet (29.24% CP); a similar protein level to cow's milk, despite no experience in selecting a diet during the pre-weaning period. It is well documented that the live weight gained at an early age is in protein and mineral form [17]. Soybean is a rich source of protein and digestible fiber [18]. Interestingly, the calves in the present study selected a diet containing high amounts of soybean meal (45.34%), but in a previous study, using similar methods with more feed ingredients, dairy cows

Table 2. Ingredients and nutrient contents of the diets selected by calves during the pre-weaning period

Feeding methods (FM)	TMR	Choice feeding		SEM	P<*	P<**	
Sex		Female	Male		Sex(S)	Female	Male
Alfalfa hay, %	10.00	6.00	5.56	0.88	0.77	0.00	0.00
Wheat bran , %	17.28	30.53	29.60	3.08	0.84	0.00	0.00
Soybean meal, %	17.73	41.25	49.43	3.75	0.14	0.00	0.00
Barley, %	52.29	19.53	12.20	2.56	0.07	0.00	0.00
Premix***, %	2.70	2.69	2.69	0.14	0.99	0.93	0.94
Compositions;							
Dry Matter (DM), %	90.77	89.87	89.69	0.07	0.07	0.00	0.00
Crude Protein (CP), %	17.94	27.68	30.79	1.34	0.11	0.00	0.00
Ether Extract (EE), %	2.59	2.45	2.44	0.05	0.87	0.01	0.02
Acid detergent Fiber (ADF),%	11.85	11.98	12.04	0.33	0.89	0.73	0.49
Neutral Detergent Fiber (NDF),%	24.99	27.17	27.18	0.58	0.98	0.00	0.00
Ash, %	7.20	6.50	8.28	0.11	0.00	0.00	0.00
Crude Fiber (CF), %	7.74	6.32	6.63	0.32	0.55	0.00	0.00
Metabolisable Energy, (ME) Mcal/kg	2.23	2.60	2.60	0.01	0.77	0.00	0.00

**Refers to differences between female and male diet preferences.*
*** Refers to difference between the diets preferred by each sex and TMR.*
**** contains limestone, salt and vitamin mineral premix used in TMR.*

Table 3. Feed and nutrient intakes, daily gain and feed to gain ratios calves fed with different feeding methods during the pre-weaning period

Feeding methods (FM)	TMR		Choice feeding		SEM	Effects (P<)		
Sex (S)	Female	Male	Female	Male		S	FM	SxFMxFM
Initial body weight, kg	36.01	38.14	36.68	38.04	1.07	0.26	0.86	0.80
Feed intake*, g/day	594.87	670.46	717.36	682.79	36.9	0.70	0.20	0.27
Daily gain, g/day	467.73*b*	564.16*a*	598.47*a*	632.27*a*	22.82	0.05	0.00	0.29
Weaning weight, kg	62.21*b*	69.74*a*	70.19*a*	73.44*a*	1.69	0.03	0.02	0.37
Crude protein intake, g/day	106.75*b*	120.31*b*	190.13*a*	212.17*a*	9.15	0.18	0.00	0.75
Ether Extract intake, g/day	13.26	14.95	17.22	15.18	0.95	0.89	0.12	0.17
Acid detergent Fiber intake, g/day	70.5	79.45	86.88	85.08	4.39	0.57	0.08	0.39
Neutral Detergent Fiber intake, g/day	148.66*b*	167.55a*b*	192.87*a*	186.33a*b*	9.24	0.64	0.02	0.34
Ash intake, g/day	42.85a*b*	48.30a*b*	45.79	48.30a*b*	2.50	0.03	0.12	0.44
Metabolisable Energyintake, Mcal/day	1.54	1.74	1.85	1.76	0.10	0.07	0.21	0.29
Crude Fiber intake, g/day	46.03	51.87	42.32	47.28	2.72	0.06	0.42	0.91
Feed to gain**	1.27	1.21	1.18	1.09	0.05	0.33	0.14	0.84

**As fed basis; ** Feed intake (g/day)/Daily gain (g/day)*
[a,b] Row means that have different superscript differ, P < 0.05

selected a diet containing small amounts of soybean meal, of just 1.48% [19].Gorgulu et al. [7], Montoro and Bach [9] and Miller-Cushon et al. [8] reported a similar trend for diet preferences of choice-fed calves with free access to feed ingredients. Calves need a high-protein and energy in the diet during their early life [18]. The calves in the present study may have preferentially chosen a soybean meal because of its high protein and energy content among the offered feed ingredients. One may question this assumption because of the low milk supply (4 l/day) in the present study, and high protein preferences may be result from low milk supply thus the diet preference should be checked higher milk supply as well.

In the current study, the choice-fed calves selected a more nutritious diet than the calves fed with TMR and maximized their nutrient intake. Atwood et al. [5] reported that animals with the opportunity to select their diet from multiple choices maximized their energy intake. Although, the calves in the choice fed group had no previous experience of diet preference, they successfully chosen the nutritious diets meeting their nutrient requirements. Researchers have previously shown that calves can readily adapt to different feeding schedules [19,20] and show an ability to learn feed cues such as structure and palatability, and learn from post-ingestive feedback by sampling novel feeds [2].

In the present study, sex had no effect on diet preference; This could be attributed to minimal differences in nutrient requirement between male and female calves during the pre-weaning period [8]. NRC [8] indicates that there is little difference in body composition between male and female calves until 100 kg of body weight.

The soybean meal preferences of the choice-fed calves resulted in greater growth rate during the pre-weaning period. Choice-fed calves had a higher daily weight gain, compared with TMR calves (615.4 vs. 516.0 g/day, $P< 0.01$). It has been established that high protein intake from starter [13] or milk replacer, increases daily weight gain during the pre-weaning period [19] NRC [8] recommends 18% CP for pre-weaning calves, and reported that energy intake is limiting, but protein intake is not limiting, for daily weight gain during the pre-weaning period under low milk supply condition. However, high preference for soybean meal increased protein and energy content of the diet consumed by the calves in the present study. The increase in protein intake is likely the reason that we observed increased daily weight gain in the choice-fed calves during the pre-weaning period.

Conversely, some researchers using similar methodology and feed ingredients have not observed any difference in performance between choice-fed and TMR-fed calves [7,9]. In the Montoro and Bach [9] study, calves preferred a diet containing 29% CP compared to the TMR having 18% CP. Calves in the Gorgulu et al. [7], study consumed a diet containing higher protein; 31–35% CP for winter and summer and 27.7–30.8% CP for female and male calves, respectively, compared to calves fed a TMR containing 18% CP. The protein preferences in these two studies were similar when compared with the protein preferences of the calves in the current study. Too much protein may increase the energy requirement for metabolic clearance of ammonia production during protein metabolism [17,7], and this could have masked the effect of choice-feeding on daily weight gain in the previous studies. Furthermore, the calves in our previous study [7], had higher initial live weight than those in the current study. This could also be an important factor for the difference between studies in response to choice feeding in respect to daily gain. Montoro and Bach [9], revealed that poor efficiency of protein intake for the choice fed calves may be a result of low energy intake. They also reported that calves failed or did not have opportunity to select an adequate combination of ingredients to achieve an increase supply of energy, which would match the consumption of protein and potentially allow an improved daily gain and efficiency of protein utilization.

This could also be supported by the similarities between the protein content of the diets selected and milk protein content being inconsistent with the energy content of the diets selected and energy content of the milk used in the study, which was 5.13 Mcal ME/kg DM [18]. The average ME and CP requirements of the calves is 4.1 Mcal/day and 185 g/day, respectively, however consumption (with milk) of ME and CP of the choice-fed calves was 4.30 Mcal/day and 326 g/day, respectively. This consumption shows that CP intake was not limiting, however ME intake may be limiting and/or not coupling with the high protein intake for daily weight gain.

Male calves had significantly higher daily weight gain than female calves during the pre-weaning period. Similar findings have been reported by others [21,22]. Conversely, other researchers [e.g. 22], reported daily weight gain during the pre-weaning period does not differ according to sex. Female calves fed with TMR consumed less feed and crude protein in the present study; this may have contributed to the decreased daily weight gain in these calves. Lower solid feed intake in the TMR-fed female calves could potentially be explained by them having a lower initial body weight, which would lead to a proportionally higher milk intake compared to male calves, as there was a standard amount of milk (4 L/day) fed to all calves during the pre-weaning period, regardless of initial body weight.

Table 4. Feed and nutrient intakes, daily gain and feed to gain ratios calves fed with different feeding methods during the post-weaning period

Feeding methods (FM)	TMR		Choice feeding		SEM	Effects (P<)		
Sex(S)	Female	Male	Female	Male		S	FM	SexXFM
Final weight, kg	87.41*b*	100.77*a*	97.64*a*	101.07*a*	2.25	0.01	0.10	0.12
Daily gain, g/day	450.12*b*	554.20*a*	490.05*ab*	493.37*ab*	25.23	0.06	0.87	0.04
Feed intake*, g/day	2470.07*b*	2894.20*a*	2851.40*a*	2767.61*ab*	75.57	0.12	0.24	0.02
Feed to gain	5.59	5.32	6.01	5.70	0.19	0.26	0.12	0.92
Crude protein intake, g/day	331.23*b*	388.11*a*	382.37*a*	371.13*ab*	10.13	0.12	0.24	0.02
Ether Extract intake, g/day	59.03*b*	69.17*a*	68.15*a*	66.14*ab*	1.80	0.12	0.24	0.02
Acid detergent Fiber intake, g/day	683.47*b*	800.83*a*	788.98*a*	765.79*ab*	20.90	0.12	0.24	0.02
Neutral Detergent Fiber intake, g/day	861.19*b*	1009.06*a*	994.14*a*	964.93*ab*	26.35	0.12	0.24	0.02
Ash intake, g/day	140.05*b*	164.10*a*	161.68*a*	156.92*ab*	4.28	0.12	0.24	0.02
Metabolisable Energy intake, Mcal/day	5.41*b*	6.34*a*	6.25*a*	6.06*ab*	0.16	0.12	0.24	0.02
Crude Fiber intake, g/day	490.22*b*	574.41*a*	565.91*a*	549.28*ab*	14.99	0.12	0.24	0.02

**As fed basis*

[a,b] Row means that have different superscript differ, P < 0.05

Table 5. Feed and nutrient intakes, daily gain and feed to gain ratios calves fed with different feeding methods during the overall period (pre- and post-weaning) of the study

Feeding method (FM)	TMR		Choice feeding		SEM	Effects (P<)		
Sex(S)	Female	Male	Female	Male		S	FM	S x FM
Initial body weight, kg	36.01	38.14	36.68	38.04	1.07	0.26	0.86	0.80
Final weight, kg	87.41 *b*	100.77*a*	97.64*a*	101.07*a*	2.25	0.01	0.10	0.12
Daily gain, g/day	458.92 *b*	559.18*a*	544.26*a*	562.82*a*	16.68	0.01	0.58	0.08
Feed intake*, g/day	1532.47*b*	1782.33*a*	1784.38*a*	1725.20*ab*	52.79	0.21	0.20	0.04
Feed to gain	3.24	3.36	3.28	3.07	0.06	0.17	0.23	0.68
Crude protein intake, g/day	218.99*c*	254.21 *b*	286.25*ab*	291.65*a*	9.15	0.10	0.00	0.23
Ether Extract intake, g/day	36.15 *b*	42.05*a*	42.68*a*	40.66*ab*	1.80	0.28	0.15	0.03
Acid detergent Fiber intake, g/day	376.98 *b*	389.87*ab*	438.96*a*	424.78*ab*	12.16	0.15	0.18	0.03
Neutral Detergent Fiber intake, g/day	504.93 *b*	588.31*a*	593.51*a*	575.63*a*	18.47	0.00	0.17	0.04
Ash intake, g/day	91.45 *b*	106.2*a*	103.73*ab*	106.82*a*	0.05	0.18	0.15	0.20
Metabolisable Energy intake, Mcal/day	3.48 *b*	4.04*a*	4.05*a*	3.91*ab*	0.13	0.22	0.20	0.05
Crude Fiber intake, g/day	268.13 *b*	313.14*a*	304.12*a*	298.28*ab*	8.99	0.11	0.38	0.04

**As fed basis*

[a,b] Row means that have different superscript differ, P < 0.05

Sex and feeding system during the pre-weaning period had no effect on any parameters investigated (P > 0.05). There was an interactive effect of sex and feeding system on daily weight gain, feed and nutrient intakes during the post-weaning period (P < 0.05). Male TMR-fed calves consumed more feed and nutrients and had higher daily weight gain compared to female calves. Male and female choice-fed calves had similar daily weight gain, feed and nutrient intake

during the post-weaning period. Female TMR-fed calves consumed less solid feed compared with male calves, possibly because of their proportionally higher milk consumption during the preweaning period. This may have decreased rumen and epithelium growth [22]. Previous research suggests that high levels of liquid feed may decrease starter intake [23-25]. The lower feed intake of the TMR-fed female calves resulted in decreased nutrient intake and reduced daily weight gain post-weaning, compared with the pre-weaning period. Similarly, Stamey et al. [26] reported an interaction between sex and diet for feed intake during the later stage of the pre-weaning period; female calves receiving conventional milk replacer had a higher starter intake compared with male calves on the same treatment and female calves fed with an enhanced milk replacer. The choice fed calves in the present study preferred high protein diets and consumed markedly high amount of protein than the calves fed TMR, but they did not responded properly during post weaning period in respect to daily weight gain.

When overall performance was evaluated, male calves had higher daily weight gain compared to female calves ($P<0.05$). Sex and feeding system interaction had significant effects on feed and nutrient intake ($P<0.05$). Male TMR-fed calves consumed more feed and nutrients compared with the female calves, however these differences were not observed in the choice-fed groups. Female calves had a better response to choice feeding and consumed similar amounts of feed and nutrients compared with male calves in the choice-fed groups, but not in the TMR-fed groups.

4. CONCLUSIONS

In this study revealed that during the preweaning period calves selected a diet containing higher CP (28–31%), when feed ingredients were supplied as a choice, compared with the standard starter protein level (18% CP). Choice fed calves had also higher daily weight gain during the pre-weaning, but not post-weaning, period. Furthermore, high preference for protein may have the long term effects on performance of young calves. It is therefore necessary to investigate the effect of early dietary preference of calves on their adult performance.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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