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Inclusion of whole corn grain in forage-free starter feeds in Holstein dairy calves: Determination of optimum level on growth performance, rumen fermentation, and blood metabolites

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Inclusion of whole corn grain in forage-free starter feeds in Holstein dairy calves: Determination of optimum level on growth performance, rumen fermentation, and blood metabolites

There is a growing interest in using whole grains as a potential alternative to forage in starter feed due to their adequate particle size and potential prevention of forage's negative effects in starter feed. This could improve dairy calves' feed intake and performance. Therefore, to determine the optimum level of whole corn grain in starter feed on feed intake, performance, health, ruminal fermentation, and blood metabolites of dairy calves, forty-eight Holstein calves [4-day-old; 41.10 ± 2.56 kg of body weight (BW), 12 per treatment] were randomly assigned to each of the following four treatments: 1) starter feed contained corn grain as ground with no whole corn grain (WC0); 2) starter feed where 33% of ground corn was replaced with whole corn grain (WC33); 3) starter feed where 66% of ground corn was replaced with whole corn grain (WC66); and 4) starter feed where 100% of ground corn was replaced with whole corn grain (WC100). For the purpose of gathering post-weaning data, the calves were weaned on day 60 and left until day 74. The experimental treatments had no significant effect on BW, but the starter feed and total dry matter intake (TDMI) tended ($P = 0.051$) to respond cubically with

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increasing WC inclusion. Throughout the entire period, the wither height tended ($P = 0.09$) to increase linearly as WC increased in starter feed. The fecal score, respiratory score and days with diarrhea did not differ between treatments. Throughout the research, calves fed the WC0 diet had lower ($P = 0.01$) rumen pH levels compared with the other treatments, and rumen acetate concentrations decreased ($P = 0.02$) cubically and acetate-to-propionate ratio tended ($P = 0.07$) to increase linearly in calves consuming WC. There were no differences in blood metabolites among the experimental groups during the overall period. Given the observed rumen fermentation modulations under the conditions of the current experiment, we concluded that grinding all the corn grain in forage-free starter feeds is not recommended for dairy calves. Feed intake-related data indicated that partial replacement (33%) of ground with whole corn could lead to greater intake.

Different levels of ground corn substitution with WC were evaluated in this study in order to determine the optimum level of WC inclusion in starter feed. There were subtle changes in the hip width and TP concentration for WC33 at d 72. Moreover, some alterations were observed in rumen fermentation with more favorable conditions (pH, VFAs, etc.) when WC was included in the feed; considering rumen modulations, we concluded that grinding all the corn grain in forage-free starter feeds is not recommended for dairy calves. However, without any clear response in growth performance among treatments, feed intake-related data indicated that partial replacement (33%) of ground with whole corn could lead to greater intake. Under conditions of this study, although there was some evidence of improvement with WC33, future studies should be done to validate the results found herein.

استفاده از دانه کامل ذرت در استارتر بدون علوفه در گوساله های شیری هلشتاین: تعیین سطح بهینه بر عملکرد رشد، تخمیر شکمبه و متابولیت های خون

علاقه فزاینده ای به استفاده از غلات کامل به عنوان جایگزین بالقوه علوفه در استارتر به دلیل اندازه ذرات کافی و جلوگیری بالقوه از اثرات منفی علوفه در خوراک استارتر وجود دارد. این می تواند مصرف خوراک و عملکرد گوساله های شیری را بهبود بخشد. بنابراین، برای تعیین سطح بهینه غلات کامل ذرت در خوراک آغازین در مصرف

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خوراک، عملکرد، سلامت، تخمیر شکمبه و متابولیت‌های خون گوساله‌های شیری، چهل و هشت گوساله هلشتاین [سن ۴ روز، ۴۱,۱۰ کیلوگرم وزن بدن (BW)، ۱۲ در هر تیمار] به طور تصادفی به هر یک از چهار تیمار زیر اختصاص داده شد: ۱) استارتر حاوی دانه ذرت آسیاب بدون دانه کامل ذرت (WC0). ۲) استارتر که در آن ۳۳ درصد ذرت آسیاب با دانه کامل ذرت (WC33) جایگزین شد. ۳) استارتر که در آن ۶۶ درصد ذرت آسیاب با دانه کامل ذرت جایگزین شد (WC66). و ۴) استارتر که در آن ۱۰۰ درصد ذرت آسیاب با دانه کامل ذرت (WC100) جایگزین شد. به منظور جمع‌آوری داده‌های پس از شیرگیری، گوساله‌ها در روز ۶۰ از شیر گرفته شدند و تا روز ۷۴ نگهداری شدند. تیمارهای آزمایشی تأثیر معنی‌داری بر وزن بدن نداشتند، اما مصرف استارتر و کل ماده خشک مصرفی (TDMI) تمایل به پاسخ درجه سه با افزایش گنجاندن دانه کامل ذرت داشتند. در طول کل دوره، ارتفاع جدوگاه تمایل به افزایش خطی داشت، وقتی دانه کامل ذرت در استارتر افزایش یافت. امتیاز مدفوع، امتیاز تنفسی و روزهای مبتلا به اسهال بین تیمارها تفاوتی نداشت. در طول تحقیق، گوساله‌هایی که با جیره WC0 تغذیه می‌شدند، سطح pH شکمبه کمتری نسبت به سایر تیمارها داشتند، و غلظت استات شکمبه به صورت درجه سه کاهش یافت و نسبت استات به پروپیونات به طور خطی در گوساله‌هایی که دانه کامل ذرت مصرف می‌کردند افزایش یافت. هیچ تفاوتی در متابولیت های خون در بین گروه های آزمایشی در طول دوره وجود نداشت. با توجه به مدولاسیون های تخمیر شکمبه مشاهده شده تحت شرایط آزمایش فعلی، ما به این نتیجه رسیدیم که آسیاب کردن تمام دانه ذرت در استارتر بدون علوفه برای گوساله های شیری توصیه نمی شود. داده های مربوط به مصرف خوراک نشان داد که جایگزینی جزئی (٪۳۳) از ذرت اسیاب با ذرت کامل می تواند منجر به مصرف بیشتر شود.

سطوح مختلف جایگزینی ذرت آسیاب با دانه کامل ذرت در این مطالعه به منظور تعیین سطح بهینه گنجاندن دانه کامل ذرت در استارتر مورد ارزیابی قرار گرفت. تغییرات ظریفی در عرض لگن و غلظت پروتئین کل برای WC33 در روز ۷۲ وجود داشت. علاوه بر این، برخی تغییرات در تخمیر شکمبه با شرایط مطلوب تر (pH، VFAs، و غیره) مشاهده شد زمانیکه دانه کامل ذرت در استارتر گنجانده شد. با در نظر گرفتن مدولاسیون شکمبه، به این نتیجه رسیدیم که آسیاب کردن تمام دانه ذرت در استارتر بدون علوفه برای گوساله های شیری توصیه نمی شود. با این حال، بدون هیچ پاسخ واضحی در عملکرد رشد در بین تیمارها، داده‌های مربوط به مصرف خوراک نشان داد که جایگزینی جزئی (٪۳۳) ذرت اسیاب با ذرت کامل می‌تواند منجر به مصرف بیشتر شود. در شرایط این مطالعه، اگرچه شواهدی مبنی بر بهبود WC33 وجود داشت، مطالعات آینده باید برای تایید نتایج یافت شده انجام شود.

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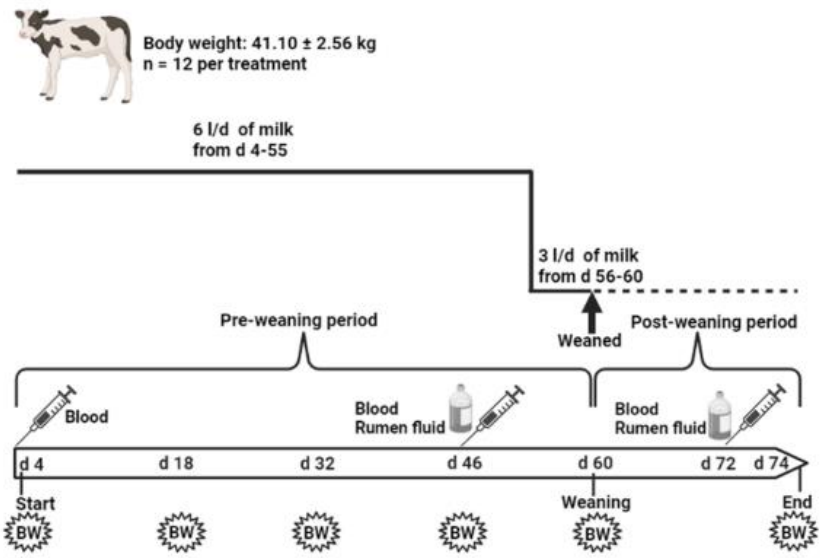

Fig. 1. The schematic diagram of experiment and the amount of whole milk consumed (L/d) by calves (6 L/d of milk from d 4–55, and 3 L/d from d 56–60 of the experiment). The calves were weaned on d 60 of age and stayed in study until d 74 of age. Figure created using BioRender (https://biorender.com).

Table 1
Ingredient, chemical composition, and particle size distribution of experimental diets.

Item	Treatments[a]			
	WC0	WC33	WC66	WC100
Ingredients (g kg/DM)				
Corn grain, ground	600	402	204	-
Corn grain, whole	-	198	396	600
Soybean meal	300	300	300	300
Wheat bran	65	65	65	65
Vitamin and mineral mix[b]	10	10	10	10
Di-calcium phosphate	10	10	10	10
Sodium bicarbonate	10	10	10	10
Salt	5	5	5	5
Bentonite	5	5	5	5
Chemical composition				
Metabolizable energy[c], MJ/kg	13.76	13.76	13.76	13.76
Crude protein, g/kg DM	192	190	193	191
Non-fiber carbohydrate[d], g/kg DM	573.9	568.1	574.3	571.5
Neutral detergent fiber, g/kg DM	128.4	130.0	127.2	131.1
Ether extract, g/kg DM	31	30	29	32
Particle size,% retained on the sieve				
4.75 mm	0.00	20.75 ± 0.35	44.75 ± 1.06	65.50 ± 0.00
2.36 mm	8.81 ± 0.26	7.35 ± 0.21	5.85 ± 0.11	5.25 ± 0.11
1.18 mm	14.69 ± 0.44	12.25 ± 0.35	9.75 ± 0.18	7.25 ± 0.18
0.6 mm	35.25 ± 1.06	29.40 ± 0.85	23.40 ± 0.42	15.00 ± 0.42
0.3 mm	21.00 ± 2.12	15.25 ± 1.06	8.00 ± 0.71	4.00 ± 0.71
0.15 mm	14.50 ± 0.71	11.00 ± 1.41	5.00 ± 0.71	2.25 ± 0.35
Pan	5.75 ± 1.06	4.00 ± 0.71	3.25 ± 0.35	0.75 ± 0.35
GMPL[e] (mm)	0.54 ± 0.02	0.88 ± 0.04	1.58 ± 0.06	2.50 ± 0.04
Particles > 1.18 mm, %	23.50	40.35	60.35	78.00

[a] WC0 = starter feed contained corn grain as ground with no whole corn grain, WC33 = starter feed where 33% of ground corn was replaced with whole corn grain, WC66 = starter feed where 33% of ground corn was replaced with whole corn grain, and WC100 = starter feed where 100% of ground corn was replaced with whole corn grain.
[b] Contained per kilogram of supplement: 500,000 IU vitamin A, 130,000 IU vitamin D, 6000 IU vitamin E, 150 g Ca, 87 g Mg, 17,500 mg Zn, 34 mg Co, 4400 mg Cu, 17,500 mg Mn, 173 mg I, 4000 mg Fe and 87 mg Se, 2500 mg monensin.
[c] Calculated from NRC (2001).
[d] Non-fiber-carbohydrate was calculated as [DM- (NDF + CP + ether extract + ash)] (NRC, 2001).
[e] GMPL = geometric mean particle length; calculated as described by the American Society of Agricultural Engineers (1983).

Table 2
Body weight, total dry matter intake, starter intake, average daily gain, and gain to feed in Holstein dairy calves fed starter feeds with different levels of whole corn grain.

	Treatments[a]				SEM	*P-value*		Contrasts *P-value*		
	WC0	WC33	WC66	WC100		Trt×Day	Day	Linear	Quadratic	Cubic
Body weight (kg)	62.05	63.99	62.84	61.91	1.68	0.66	< 0.01	0.55	0.76	0.47
TDMI[b] (g DM/d)	1197	1300	1228	1187	35.45	0.99	< 0.01	0.20	0.39	0.051
Starter (g DM/d)	625	728	656	615	35.45	0.99	< 0.01	0.20	0.39	0.051
Days to 1 kg/starter intake/day for 3 consecutive days	58.5	56.8	58.2	59.0	1.03	–	–	0.50	0.68	0.17
Average daily gain (g/d)	703	785	759	730	35.63	0.71	< 0.01	0.17	0.45	0.49
Feed efficiency[c]	0.60	0.62	0.63	0.61	0.02	0.82	< 0.01	0.26	0.82	0.94

[a] WC0 = starter feed contained corn grain as ground with no whole corn grain, WC33 = starter feed where 33% of ground corn was replaced with whole corn grain, WC66 = starter feed where 33% of ground corn was replaced with whole corn grain, and WC100 = starter feed where 100% of ground corn was replaced with whole corn grain.
[b] TDMI = total Dry matter intake (whole milk, starter feed, and forage).
[c] kg of BW gain/kg of total DMI.

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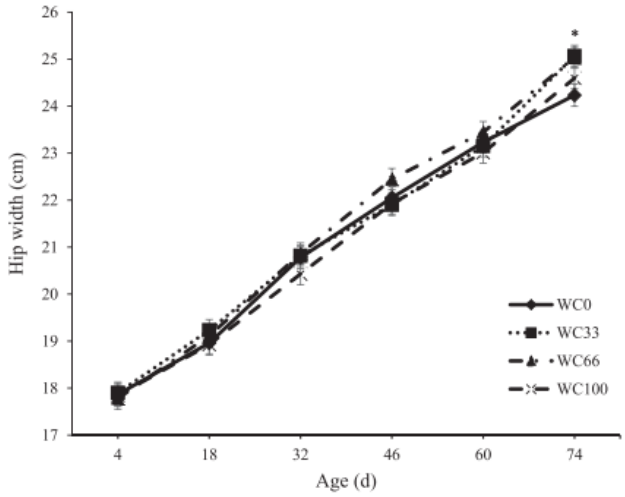

Fig. 2. Hip width for calves fed starter feed including corn grain as ground with no whole corn grain (WC0), 33% of ground corn replaced with whole corn grain (WC33), 66% of ground corn replaced with whole corn grain (WC66), and 100% of ground corn replaced with whole corn grain (WC100). The SEM = 35.63. Effects in model (mixed): treatment (Trt): $P < 0.56$; Day: $P < 0.01$; Trt × Day: $P = 0.03$. Linear effect: $P < 0.22$; quadratic effect: $P < 0.64$; cubic effect: $P < 0.61$. The sign * indicate a significant difference ($P < 0.05$) between calves fed WC0 compared with WC33 and WC66 at a given time point (Post-weaning period). Error bars represent SEM.

Table 3
Structural growth measurements in Holstein dairy calves fed starter feed with different levels of whole corn grain.

	Treatments[a]				SEM	*P-value*		Contrasts *P-value*		
	WC0	WC33	WC66	WC100		Trt×Day	Day	Linear	Quadratic	Cubic
Withers height (cm)	84.61	84.83	85.35	84.66	0.31	0.56	< 0.01	0.09	0.45	0.86
Hip Height (cm)	86.59	86.79	87.36	86.89	0.35	0.67	< 0.01	0.17	0.70	0.51
Hip width (cm)	21.19	21.34	21.45	21.12	0.18	0.03	< 0.01	0.22	0.64	0.61
Heart girth (cm)	91.88	91.90	92.04	91.15	0.53	0.67	< 0.01	0.61	0.42	0.38
Body length (cm)	73.38	73.33	73.49	73.74	0.59	0.38	< 0.01	0.98	0.86	0.61

[a] WC0 = starter feed contained corn grain as ground with no whole corn grain, WC33 = starter feed where 33% of ground corn was replaced with whole corn grain, WC66 = starter feed where 33% of ground corn was replaced with whole corn grain, and WC100 = starter feed where 100% of ground corn was replaced with whole corn grain.

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Table 4
Health status of Holstein dairy calves fed starter feed with different levels of whole corn grain.

	Treatments[a]				SEM	*P-value*		Contrasts *P-value*		
	WC0	WC33	WC66	WC100		Trt×Day	Day	Linear	Quadratic	Cubic
Fecal score[b]	1.14	1.11	1.12	1.16	0.03	0.48	< 0.01	0.31	0.87	0.41
Respiratory score[c]	1.05	1.03	1.04	1.05	0.02	0.21	0.75	0.65	0.92	0.92
Days with diarrhea[d]	6.47	4.95	5.49	6.58	0.12	–	–	0.15	0.71	0.20
Days with increased respiratory score[e]	2.55	2.25	2.71	2.72	0.19	–	–	0.83	0.33	0.12
Medical days[f]	4.45	4.85	3.55	4.05	0.14	–	–	0.45	0.44	0.21
Treatment bouts	1.88	1.87	1.41	1.91	0.22	–	–	0.38	0.50	0.80
Number of used drugs	4.41	4.31	3.45	3.78	0.14	–	–	0.36	0.81	0.31
Fluid therapy days	0.43	0.16	0.07	0.37	0.66	–	–	0.04	0.64	0.77

[a] WC0 = starter feed contained corn grain as ground with no whole corn grain, WC33 = starter feed where 33% of ground corn was replaced with whole corn grain, WC66 = starter feed where 33% of ground corn was replaced with whole corn grain, and WC100 = starter feed where 100% of ground corn was replaced with whole corn grain.
[b] Where 1 = firm, 2 = soft, 3 = soft and running, and 4 = watery.
[c] Where 1 = normal, 2 = slight cough, 3 = moderate cough, 4 = moderate to severe cough, 5 = severe and chronic cough.
[d] Days with fecal score ≥ 2.
[e] Days with respiratory score ≥ 2.
[f] Treatment was carried out under on-farm protocol and according to the farm's veterinarian.

Table 5
Ruminal pH and volatile fatty acid concentrations in Holstein dairy calves fed starter feed with different levels of whole corn grain.

	Treatments[a]				SEM	*P-value*		Contrasts *P-value*		
	WC0	WC33	WC66	WC100		Trt×Day	Day	Linear	Quadratic	Cubic
Ruminal pH	5.92	6.24	6.48	6.55	0.07	0.23	0.85	< 0.01	0.01	< 0.01
Total VFA (mM/L)	53.2	50.3	44.9	43.4	3.47	0.29	< 0.01	0.26	0.53	0.53
Acetate (mM)	29.2	27.8	24.6	21.6	2.1	0.20	< 0.01	0.43	0.32	0.02
Propionate (mM)	17.5	14.3	12.8	14.4	1.61	0.34	0.17	0.06	0.63	0.53
Butyrate (mM)	5.08	6.52	6.08	6.15	0.64	0.91	< 0.01	0.25	0.26	0.96
Valerate (mM)	1.46	1.62	1.49	1.33	0.22	0.59	< 0.01	0.69	0.99	0.40
Acetate: propionate	1.65	2.00	2.10	1.73	0.19	0.73	0.22	0.07	0.98	0.69

[a] WC0 = starter feed contained corn grain as ground with no whole corn grain, WC33 = starter feed where 33% of ground corn was replaced with whole corn grain, WC66 = starter feed where 33% of ground corn was replaced with whole corn grain, and WC100 = starter feed where 100% of ground corn was replaced with whole corn grain.

Table 6
Serum glucose, BHB, total protein, albumin, and BUN concentrations in Holstein dairy calves fed starter feed with different levels of whole corn grain.

	Treatments[a]				SEM	*P-value*		Contrasts *P-value*		
	WC0	WC33	WC66	WC100		Trt×Day	Day	Linear	Quadratic	Cubic
Glucose(mg/dl)	119.4	118.1	115.7	119.8	3.87	0.59	< 0.01	0.47	0.73	0.93
BHB (mmol/l)	0.14	0.14	0.13	0.12	0.008	0.99	< 0.01	0.92	0.51	0.18
Total Protein (g/dl)	6.62	6.77	6.79	6.72	0.11	0.09	< 0.01	0.22	0.72	0.95
Albumin (g/dl)	3.51	3.58	3.61	3.59	0.05	0.33	< 0.01	0.17	0.55	0.59
BUN (mg/dl)	22.3	23.2	21.7	21.5	1.41	0.94	< 0.01	0.99	0.83	0.37

[a] WC0 = starter feed contained corn grain as ground with no whole corn grain, WC33 = starter feed where 33% of ground corn was replaced with whole corn grain, WC66 = starter feed where 33% of ground corn was replaced with whole corn grain, and WC100 = starter feed where 100% of ground corn was replaced with whole corn grain.

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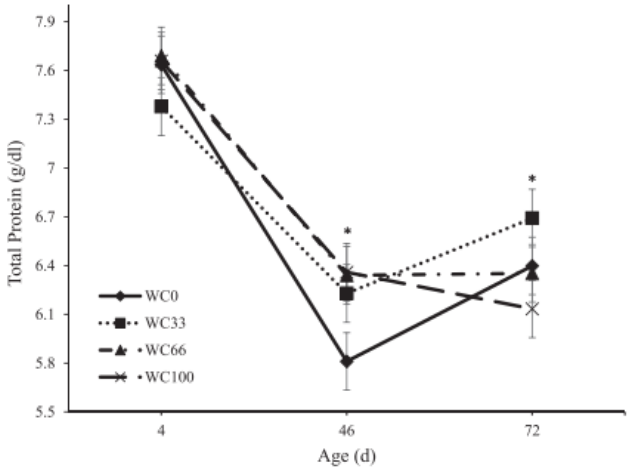

Fig. 3. Serum Total protein concentrations for calves fed starter feed including corn grain as ground with no whole corn grain (WC0), ground corn with 33% whole corn grain (WC33), ground corn with 66% whole corn grain (WC66), and 100% of ground corn replaced with whole corn grain (WC100). The SEM = 0.11. Effects in model (mixed): treatment (Trt): $P < 0.63$; Day: $P < 0.01$; Trt × Day: $P = 0.09$. Linear effect: $P < 0.22$; quadratic effect: $P < 0.72$; cubic effect: $P < 0.95$. For each time point, the sign * indicate a significant difference ($P < 0.05$) between treatments. Error bars represent SEM.