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SUPPLEMENTING LACTATION DIETS WITH HERBAL EXTRACT MIXTURE DURING SUMMER IMPROVES THE PERFORMANCE OF SOWS AND NURSING PIGLETS

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Abstract

A total of 45 Landrace × Yorkshire multiparous sows were used to evaluate the effect of dietary herbal extract mixture (*Scutellaria baicalensis* and *Lonicera japonica*, HEM) supplementation in lactating sows under heat stress. Sows were randomly allotted to 1 of 3 dietary treatments: 1) CON, basal diet; 2) TRT1, basal diet with 5 g/d HEM; 3) TRT2, basal diet with 10 g/d HEM. During lactation, dietary HEM supplementation linearly increased (P<0.05) the average daily feed intake (ADFI) and linearly decreased (P<0.05) backfat loss. The digestibility of dry matter (DM) was increased after farrowing (linear, P<0.05; quadratic, P<0.05) and weaning (linear, P<0.05) by HEM supplementation. Furthermore, HEM treatment led to a lower (linear, P<0.01) serum cortisol level. In addition, administration of HEM improved (linear, P<0.05) the piglets weaning weight and overall average daily gain (ADG) during suckling period. Meanwhile, on day 7 and 14 after birth, the fecal score of piglets was decreased (linear, P<0.01) by HEM supplementation. Taken together, under high ambient temperatures, inclusion of HEM to lactation diets could improve the feed intake, digestibility of DM, piglets weaning weight and ADG, while decreasing backfat loss, serum cortisol level, as well as the diarrhea of piglets.

Key words: lactating sows, heat stress, herbal extract mixture, performance, piglets

Voluntary feed intake of lactating sows is often inadequate to meet the nutrient requirements for maintenance and milk production, and body reserves can be partly depleted, which leads to subsequent reproductive problems (Quiniou and Noblet, 1999). The high ambient temperature is one of the most important extrinsic factors that influence voluntary feed intake. Previously, numerous studies have documented that when ambient temperature is above 25°C, feed intake and milk production of lactating sows will decrease, and consequently reduce the litter growth rate (Mullan et al., 1992; Black et al., 1993).

It is well suggested that nutritional manipulations could be proposed as possible strategy to offset the consequences of heat stress in farm animals (Renaudeau et al., 2012). The herbs and their extract were recognised for their ability to improve health status of animals against hot climates. These properties include antibacterial, antiviral, and stimulation of immune function (Wenk, 2003). Additionally, herbs could contribute to the desired organoleptic qualities of the diets and stimulate the appetite, as well as improve digestive tract function by increasing hydrochloric and enzyme secretion, thus improving the feed intake (Frankič et al., 2009). Among the variety of herbs, *Scutellaria baicalensis* and *Lonicera japonica* are both famous traditional medicinal plants in Eastern Asia. In addition to the beneficial effect on immune function and appetite, *S. baicalensis* and *L. japonica* have been used to "clear away the body heat" in clinic (Pei, 1991; Li et al., 2004; Shang et al., 2011). As the main active component, the flavones existing in these two herbs (Table 1) could inhibit the expression of heat shock proteins (Hosokawa et al., 1990), thus ameliorating the adverse effect of heat stress. Furthermore, there is some evidence that *S. baicalensis* possess an anti-stress effect in rats (Ryu et al., 2004).

Table 1. The main active components of *Scutellaria baicalensis* and *Lonicera japonica*

Main active components	Compounds	Effect	Reference
Scutellaria baicalensis			
Flavones	Baicalin, baicalein, wogonin, oroxylin A	Ameliorate heat stress, anti-allergic, anti-tumor, anti-inflammatory, antioxidant	Hosokawa et al., 1990 Li et al., 2004
Lonicera japonica			
Organic acids	Chlorogenic acid, isochlorogenic acid, caffeic acid	Antioxidative, anti-tumor, anti-inflammatory, antibacterial, antiviral	Shang et al., 2011
Flavones	Chrysoeriol, luteolin	Ameliorate heat stress, anti-tumor, anti-inflammatory, antioxidant	Hosokawa et al., 1990 Shang et al., 2011
Iridoids	Loganin	Anti-inflammatory	Shang et al., 2011
Saponins	Loniceroside, hederagenin	Anti-inflammatory	Shang et al., 2011

In swine production, the application of phytogenic additive is not a new idea, however, in comparison with the vast number of positive results reported on the herbal extract supplementation to weaning, growing and finishing pigs diets (Nofrarias et al., 2006; Peeters et al., 2006; Szewczyk et al., 2006; Kong et al., 2007 a, b; Wang et al., 2007; Kong et al., 2009; Yan et al., 2011 a, b; Huang et al., 2012; Yan et al., 2012), there is relatively little published data about herbs for lactating sows. Moreover, there is a lack of sufficient evidence to show the effects of dietary herbal extract supplementation on the performance of lactating sows under heat stress and the nursing piglets responses. Additionally, from the foregoing, we wondered if *S. baicalensis* and *L. japonica* could ameliorate heat stress and improve the performance of lactating sows. Therefore, this study was conducted to evaluate the effect of herbal extract mixture (HEM) made up of *S. baicalensis* and *L. japonica* supplementation on reproductive performance of lactating sows under heat stress.

Material and methods

All procedures involving animals were approved by the Animal Care and Use Committee of Dankook University.

Preparation of herbal extract mixture

The dietary additive used in the present study was composed of two dried herbs including *Scutellaria baicalensis* and *Lonicera japonica*, which were bought from a local medicine market in Korea. In brief, the dried plant material was chopped and ground to pass 100 mesh (2 mm). Then, 100 kg of each powdered medicinal herb was extracted with 70% methanol (200 L) by a large-scale extractor (CoBiotechk, Seoul, Korea) at room temperature for 24 h. The 70% methanol solution was filtered 2 to 3 times through cheesecloth, and the filtrate was evaporated under vacuum, after which the evaporated filtrate was freeze-dried and crushed in the form of powder extract. Finally, a mixture of 55% *Scutellaria baicalensis* powder extract, 25% *Lonicera japonica* powder extract, and 20% carrier (wheat bran), was used as HEM for the sows' diets.

Animals, housing and treatment

The experiment was conducted during summer season in Dankook University (Cheonan campus) farm, with an ambient temperature of 28.39±0.84°C and a relative humidity of 68.72±4.15%. The temperature and relative humidity of the pig house were determined by using a real-time hygrometer (IAQ-2-TH, GR Technology, Changsha, China), the daily average value was obtained and calculated from the hygrometer. A total of 45 Landrace × Yorkshire, multiparous sows (n = 15/treatment) were used in this 36-day trial. Approximately 7 days before the expected time of parturition, sows were moved into the farrowing facility and allotted to one of three dietary treatments: 1) CON, basal diet; 2) basal diet with 5 g/d HEM; 3) basal diet with 10 g/d HEM. Sows were provided with feed on each morning and evening, the feed consumption was limited to 2.5 kg/d during gestation and was increased gradually by 1 kg/d after farrowing until reaching the maximal allowance. Dietary nutrients were formulated to meet or exceed the NRC (2012) recommendations (Table 2). Sows were housed in farrowing crates (2.1 m × 0.6 m) which contained an area (2.1 m × 0.6 m) for newborn piglets on each side. Heat lamps were provided for piglets. Piglets were treated according to routine management practices that included teeth clipping, tail docking, ear notching and subcutaneous iron dextran injections (1 mL per pig) within 24 h of birth. Sows were given free access to water throughout the experimental period, and the piglets received no creep feed.

Table 2. Ingredient composition of experimental diets as-fed basis[1]

Item	Gestation diet	Lactation diet
Ingredient (%)		
corn	57.10	51.18
soybean meal, 46% CP	10.65	24.61
wheat bran	12.00	4.00
rice bran	6.00	5.00
tallow	3.59	6.05
rapeseed meal	3.70	2.50
molasses	3.60	3.50
dicalcium phosphate	1.52	1.64
limestone	0.99	0.70
salt	0.60	0.50
vitamin premix[2]	0.10	0.10
mineral premix[3]	0.10	0.10
lysine, 98%	0.05	0.12
Calculated composition		
ME (MJ/kg)	3.19	3.42
CP (%)	13.10	17.10
Lys (%)	0.65	1.00
Crude fat (%)	6.89	9.10
Ca (%)	0.87	0.85
P (%)	0.76	0.73

[1]Herbal extract mixture was included in the later period of gestation and lactation diet by replacing the same amount of corn.

[2]Provided per kg of complete diet: vitamin A, 10,000 IU; vitamin D_3, 2,000 IU; vitamin E, 48 IU; vitamin K_3, 1.5 mg; riboflavin, 6 mg; niacin, 40 mg; D-pantothenic acid, 17 mg; biotin, 0.2 mg; folic acid, 2 mg; choline, 166 mg; vitamin B_6, 2 mg; and vitamin B_{12}, 28 µg.

[3]Provided per kg of complete diet: Fe (as $FeSO_4{\cdot}7H_2O$), 90 mg; Cu (as $CuSO_4{\cdot}5H_2O$), 15 mg; Zn (as $ZnSO_4$), 50 mg; Mn (as MnO_2), 54 mg; I (as KI), 0.99 mg; and Se (as $Na_2SeO_3{\cdot}5H_2O$), 0.25 mg.

Sampling and measurements

Individual sow was weighed and scanned for backfat thickness before 4 days of parturition, and within a few hours after day of farrowing, as well as on day 29 of lactation to determine weight and backfat loss. The backfat thickness of the sows (5 cm off the midline at the 10th rib) was measured using a real-time ultrasound instrument (PigLog 105; SFK Technology, Herlev, Denmark). During lactation, feed consumption was recorded for each sow to calculate average daily feed intake (ADFI). During the experimental period, numbers of piglets alive and dead per litter were recorded to calculate survival ratio. Individual piglet weight was measured at birth and weaning (day 29 of lactation) to determine weight gain. After weaning, the estrus interval was recorded for each sow.

One week before farrowing and weaning, sows were fed diets mixed with chromic oxide (Cr_2O_3, at 0.2% level) as an indigestible marker to calculate apparent total tract digestibility (ATTD) of dry matter (DM) and nitrogen (N), and gross energy (Ball and Aherne, 1987). Before two days of farrowing and weaning, fecal samples were collected from each sow via rectal massage. All fecal samples, as well as feed samples, were stored at –20°C until analysis. Before chemical analysis, fecal samples were thawed at 57°C for 72 h, after which they were ground to pass through a 1-mm screen. All feed and fecal samples were analyzed for DM (method 930.15, AOAC, 2007) and N (method 990.03, AOAC, 2007). Chromium was analyzed via UV absorption spectrophotometry (Shimadzu UV-1201, Shimadzu, Kyoto, Japan). Gross energy was determined using a Compensated Jacket Calorimeter 6100 (Parr Instrument Co., Moline, IL, USA).

At the beginning and the end of experiment, blood samples were taken by jugular venipuncture using vacuum tubes (Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ) from each sow. After collection, the serum samples from vacuum tubes were centrifuged (2,000 × g) for 30 min at 4°C. The blood aspartate transaminase (AST), alanine aminotransferase (ALT), γ-glutamyl transpeptidase (γ-GTP) concentrations and glucose levels were assessed using an automatic biochemistry analyzer (HITACHI 747, Japan). Anaplastic lymphoma kinase (ALK), triiodothyronine (T3), thyronine (T4), and cortisol levels were determined by using a radioimmunoassay kit (Diagnostic Products Co., USA). The adreno-cortico-tropic-hormoneurea (ACTH) and prolactin was measured by Cobra 5010 Quantum (Diagnostic Products Co., USA).

Fecal scores of piglets on day 7, 14, 21 and 29 (weaning) after farrowing were visually assessed using a subjective score on a five-point scale ranging from 1 to 5 according to the method of Hu et al. (2012): 1 = hard feces, 2 = firm well formed, 3 = soft and partially formed feces, 4 = loose, semi-liquid feces, and 5 = watery feces. A score of 4 or 5 was considered as severe diarrhea.

Statistical analyses

All experimental data were analyzed using the GLM procedure of SAS (SAS 8.0, Inst. Inc., Cary, NC, USA), the sow and litter of piglets was used as the experimental unit. Polynomial contrasts were used to determine the linear and quadratic effects of increasing HEM levels. Probability values <0.05 were considered as significant.

Results

Sow performance

As presented in Table 3, the lactation ADFI was linearly increased (P<0.01) by dietary supplementation of HEM. Additionally, during lactation, the inclusion of HEM decreased (linear, P<0.05) the backfat loss. Sow body weight loss and backfat loss after farrowing, estrus interval, and litter numbers were not affected (P>0.05) by HEM supplementation.

Nutrient digestibility

As shown in Table 4, the inclusion of HEM increased the ATTD of DM after farrowing (linear, P<0.05; quadratic, P<0.05) and weaning (linear, P<0.05). The addition of HEM in the lactation diets had no effect (P>0.05) on ATTD of N and energy.

Table 3. Effects of herbal extract mixture supplementation on performance in lactating sows[1]

Items	CON	TRT1	TRT2	SEM[2]	P-value	
					linear	quadratic
Average parity	3.7	3.5	3.5	0.4	0.200	0.067
Litter						
no. of piglets	11.2	11.3	11.5	1.1	0.390	0.456
weaned piglets	10.4	10.4	10.6	0.8	0.091	0.187
BW (kg)						
before farrowing[3]	201.4	201.1	198.2	3.2	0.482	0.754
after farrowing	183.7	183.4	179.5	3.0	0.329	0.619
weaning	174.0	173.9	171.2	2.7	0.454	0.682
body weight loss1[4]	17.73	17.63	18.76	0.74	0.336	0.501
body weight loss2[4]	9.69	9.51	8.37	0.47	0.077	0.425
ADFI (kg)						
lactation	6.84 b	6.95 b	7.63 a	0.12	0.018	0.086
Backfat thickness (mm)						
before farrowing[3]	20.7	21.0	20.5	0.8	0.886	0.680
after farrowing	18.8	19.8	19.2	0.7	0.724	0.315
weaning	17.6	18.8	18.5	0.5	0.227	0.210
Backfat thickness loss1[5]	1.83	1.17	1.33	0.35	0.328	0.346
Backfat thickness loss2[5]	1.17 a	1.00 a	0.67 b	0.16	0.038	0.667
Estrus interval (d)	4.7	4.5	4.5	0.2	0.599	0.761

[1]CON, basal diet; TRT1, CON + herbal extract mixture 5 g/d; TRT2, CON + herbal extract mixture 10 g/d.
[2]Standard error of the means.
[3]Before farrowing: before 4 days.
[4]Body weight loss: 1 – before farrowing to after farrowing; 2 – after farrowing to weaning.
[5]Backfat thickness loss: 1 – before farrowing to after farrowing; 2 – after farrowing to weaning.
a, b – means in the same row with different letters differ (P<0.05).

Table 4. Effects of herbal extract mixture supplementation on nutrient digestibility in lactating sows[1]

Items (%)	CON	TRT1	TRT2	SEM[2]	P-value	
					linear	quadratic
After farrowing						
DM	73.04 b	76.13 a	76.29 a	0.522	0.013	0.045
N	70.99	71.11	70.91	0.802	0.949	0.872
energy	72.38	73.14	73.44	0.598	0.237	0.766
Weaning						
DM	72.84 b	75.69 a	75.86 a	0.845	0.024	0.218
N	74.28	74.12	74.56	1.144	0.863	0.833
energy	73.65	73.80	74.65	0.876	0.434	0.745

[1]CON, basal diet; TRT1, CON + herbal extract mixture 5 g/d; TRT2, CON + herbal extract mixture 10 g/d.
[2]Standard error of the means.
a, b – means in the same row with different letters differ (P<0.05).

Blood profiles

Dietary HEM supplementation reduced (linear, P<0.001) serum cortisol level at the end of the experiment (Table 5). There were no differences (P>0.05) in serum concentration of AST, ALT, γ-GT, ALK, glucose, T3, T4, ACTH and prolactin among dietary treatments at both beginning and weaning.

Table 5. Effects of herbal extract mixture supplementation on blood profiles in lactating sows[1]

Items	CON	TRT1	TRT2	SEM[2]	P-value	
					linear	quadratic
AST (U/L)						
beginning	72	35	33	7	0.338	0.748
weaning	30	27	24	2	0.081	0.895
ALT (U/L)						
beginning	45	39	38	5	0.413	0.685
weaning	34	32	31	2	0.260	0.787
γ-GT (U/L)						
beginning	59	51	44	7	0.155	0.943
weanling	48	43	41	10	0.646	0.894
ALK (U/L)						
begining	123	103	105	12	0.251	0.430
weaning	111	119	102	4	0.180	0.732
Glucose (mg/dL)						
beginning	74	75	78	2	0.183	0.887
weaning	73	75	78	4	0.348	0.880
T3 (ng/dL)						
beginning	118.5	110.7	101.4	14.0	0.356	0.960
weaning	112.1	110.5	107.9	5.6	0.715	0.962
T4 (ug/dL)						
beginning	7.02	6.54	6.34	0.40	0.206	0.760
weaning	4.38	4.08	3.93	0.19	0.163	0.777
ACTH (pg/mL)						
beginning	4.2	4.0	4.1	0.4	0.890	0.811
weaning	7.1	6.7	6.8	0.9	0.798	0.792
Cortisol (ug/dL)						
beginning	3.66	2.88	2.83	0.46	0.227	0.529
weaning	3.62 a	2.24 b	1.98 b	0.24	<0.001	0.071
Prolactin (ng/mL)						
beginning	0.38	0.40	0.43	0.03	0.458	1.000
weaning	0.04	0.04	0.0	0.01	0.244	0.816

[1]CON, basal diet; TRT1, CON + herbal extract mixture 5 g/d; TRT2, CON + herbal extract mixture 10 g/d.
[2]Standard error of the means.
a, b – means in the same row with different letters differ (P<0.05).

Table 6. Effects of herbal extract mixture supplementation on growth performance in suckling piglets[1]

Items	CON	TRT1	TRT2	SEM2	P-value	
					linear	quadratic
Piglet survival (%)	93.5	92.7	92.7	1.0	0.963	0.978
BW (kg)						
birth	1.432	1.434	1.590	0.08	0.187	0.478
weaning	6.957 b	7.061 b	7.595 a	0.17	0.017	0.311
ADG (g)						
overall	197 b	201 b	214 a	4.1	0.012	0.365

[1]CON, basal diet; TRT1, CON + herbal extract mixture 5 g/d; TRT2, CON + herbal extract mixture 10 g/d.
[2]Standard error of the means.
a, b – means in the same row with different letters differ (P<0.05).

Table 7. Effects of herbal extract mixture supplementation on fecal score in suckling piglets[1]

Items	CON	TRT1	TRT2	SEM[2]	P-value	
					linear	quadratic
Fecal score						
7 d	4.0 a	4.0 a	3.7 b	0.1	0.002	0.071
14 d	3.8 a	3.4 ab	3.1 b	0.1	0.002	0.081
21 d	3.2	3.1	3.0	0.1	0.150	1.000
weaning	3.3	3.3	3.1	0.2	0.538	0.721

[1]CON, basal diet; TRT1, CON + herbal extract mixture 5 g/d; TRT2, CON + herbal extract mixture 10 g/d.
[2]Standard error of the means.
a, b – means in the same row with different letters differ (P<0.05).

Performance and fecal score of piglets

There were no differences (P>0.05) in piglet birth weight and survival among treatment groups (Table 6). The weaning weight and overall ADG was improved (linear, P<0.05) by HEM supplementation. On day 7 and 14 after birth, the fecal score of piglets was linearly decreased (P<0.01) by inclusion of HEM (Table 7).

Discussion

Milk yield of lactating sows is critical to the survival of neonatal piglets and their growth prior to weaning, thus, the great milk yield is a prerequisite for pig herds to be profitable (Harrell et al., 1993). Maximum sow milk output requires that feed intake is maximised. There is considerable evidence that high ambient temperature has a direct effect on reducing voluntary feed intake and milk production of the sows (Prunier et al., 1997; Quiniou and Noblet, 1999; Renaudeau et al., 2001). This reduction seems to be an adaptation that decreases heat production due to the thermic effect of feed (Noblet and Shi, 1993). It has been suggested that herbs could influence the eating pattern and stimulate the appetite of the animals, and subsequently increase the total feed intake (Wenk, 2003). Likewise, there are many reports on improved feed intake through herbal additives in swine (Peeters et al., 2006; Szewczyk et al., 2006; Wang et al., 2007; Yan et al., 2011 a, b; Huang et al., 2012; Yan et al., 2012). However, the scientific information on the influence of herbal products on feed intake of sows is limited. In this study, a higher ADFI of sows in the HEM treatments was observed. With regards to the feed intake of lactating sows, the greater litter size and piglet birth weight can also increase sow feed intake because of a larger nutrient requirement for milk production. However, there were no significant differences in litter size and piglet birth weight in this study, therefore, the improved lactation ADFI could mainly be attributed to the dietary treatment. Similar results were obtained by Allan and Bilkei (2005), who demonstrated that dietary supplementation of 1000 ppm herb (oregano) to multiparous sows led to higher daily voluntary feed intake compared to non-treated sows. Zhong et al. (2011) also reported that a phytogenic feed additive (at 0.04% level) increased the ADFI of lactating sows. Furthermore, it should be noted that supplementation of HEM to sow lactation diets obviously decreased backfat loss. In fact, previous studies have reported that high ambient temperature induces a decrease of total feed intake, and subsequently increases mobilization of body reserves (Quiniou and Noblet, 1999). As known, nutrients for milk production come from feed and body reserves, and most of the BW loss during lactation corresponds to the fat tissue depletions implied in meeting the nutritional deficit of sows for milk production (Noblet et al., 1998). Even if the subsequent reproductive performance were not tested in the current study, available results clearly indicated that increased depletion of body reserves has major consequences on reproductive performance of sows (Quesnel et al., 1998). The present results suggested that the HEM could moderate the mobilization of body reserves of lactating sows through increasing feed intake under a hot condition.

In addition to feed intake, the nutrient digestibility of lactating sows can also influence the milk yield. In the present study, the ATTD of DM was improved by HEM supplementation. In agreement with our results, Wang et al. (2008) suggested that phytogenic substances increased the digestibility of DM during lactation. It has been documented that a wide range of spices, herbs, and their extracts exert beneficial actions on the digestive tract, such as prevention from flatulence, stimulation of digestive secretions (e.g., saliva), bile, and mucus, as well as enhanced activity of digestive enzymes of gastric mucosa (Chrubasik et al., 2005; Srinivasan, 2005). Czech et al. (2009) have confirmed that the beneficial effect of herbs could be ascribed to the positive active substances on the digestive processes and nutrient metabolism. Huang et al. (2012) also indicated that medicinal plants supplementation provided a healthy and functional intestine, which in turn enhanced the nutrient digestibility. Therefore, the increased digestive capacity may be considered the primary reason for the improvement of nutrient digestibility of the sows.

The serum cortisol levels are often used as major physiological indicators of heat stress in animals (Abilay et al., 1975; Quiniou and Noblet, 1999). It is clear that heat stress can stimulate the release of cortisol (Brenner et al., 1998). According to Lee et al. (2007), the *S. chinensis* and *S. baicalensis* extract mixture could reduce the serum cortisol levels in an acute stress model of mice. Similar results in finishing pigs were obtained by Wang et al. (2007). In accordance with these findings, this study demonstrated that supplementation of HEM generated a decrease of serum cortisol. This decrease could be attributed to the anti-stress, tranquilizing and sedative properties contained in active compounds of *S. baicalensis* and *L. japonica*, such as flavonoids, organic acids, iridoids and saponins (Table 1) (Pei, 1991; Shang et al., 2011). Besides, higher levels of cortisol in the bloodstream have negative effects on reducing immunity (Segerstrom and Miller, 2004). The immunomodulatory activity of *S. baicalensis* and *L. japonica* can improve sows' health status in response to heat stress as well. Such beneficial effects may also be responsible for the boosted feed intake and nutrient digestibility in this study.

Alternatively, the obtained data of this study indicated that piglets weaned from HEM supplemented sows had a greater weaning weight and overall ADG. The superior growth rates of these piglets suggested that the HEM supplementation might improve the sows' milk production, and this improvement of milk output may be a result of enhanced feed intake and nutrient digestibility. Consistent with our study, Ilsley et al. (2002) reported that inclusion of an herbal extract blends to lactation diet enhanced piglet performance and resulted in higher weight at weaning. Similar effects were also observed by Zhong et al. (2011), who reported that supplementation of 0.04% phytogenic additive to sows had a positive effect on the litter performance. Taking into account the fecal score of piglets, the present study showed that dietary supplementation of HEM significantly decreased the fecal score at days 7 and 14 after birth. Based on the available literature, it is suggested that herbal extract supplementation could increase milk quality through two mechanisms. On the one hand, it has been suggested that the herbs could lead to an improvement in antibodies levels of colostrum (Watson, 1980). In this regard, Mcintosh et al. (2003) reported that herbal extract (essential oil derived from oregano) supplementation decreased populations of undesirable microorganisms and stimulated the secretion of antibodies, thus positively influencing IgG and IgA level in colostrum. Zhong et al. (2011) also demonstrated that the IgG concentration of milk was increased at 7 d of lactation by 0.02% and 0.04% phytogenic additive supplementation. On the other hand, the beneficial properties of herbal extract such as antimicrobial, antiviral and stimulation of immune system could improve uterine involution and protect the sow from possible postpartum urogenital infections (Bilkei, 1995). Furthermore, the anti-inflammatory and antioxidant activities are able to decrease the prevalence of mastitis (Amrik and Bilkei, 2004).

Conclusions

In summary, this study demonstrated that supplementation of *S. baicalensis* and *L. japonica* extract mixture to lactation diets during summer could increase feed intake and nutrient digestibility of sows while reducing the serum cortisol levels. The herbal products supplementation also improved the growth rate of nursing piglets and decreased piglets' diarrhea. These findings provided a potential nutritional manipulation strategy to ameliorate the adverse effect of seasonal heat stress in lactating sows.

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