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Effect of Mixed Mineral-Enriched Essential Oils Supplementation on Milk Production and Feed Efficiency of Lactating Dairy Cows

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Abstract: This study aimed to determine milk production and efficiency of feed utilization of a mixed mineral-enriched essential oils supplementation of lactating dairy cows. Forty-eight Holstein-Friesian cows with a 3.45±0.58 body condition score and 187.08±21.53 days in milk were randomly allocated to two dietary treatments for 46 days. Treatments consisted of no supplementation (CON) or supplementation (AGB) of 0.5% of Agromix Booster® in the Total Mix Ration (TMR). All cows were given the same TMR twice a day (the only difference was the presence or absence of Agromix Booster®). Daily monitoring of milk production, composition, and dry matter intake of cows was calculated and feed efficiency was determined. Compared with CON, cows fed AGB showed an increase in milk yield (P<0.05). However, no significant effects were detected on milk fat content and yield, protein content and yield, lactose content and yield, solid non-fat content, and total solids content (P>0.05). Furthermore, AGB supplementation increased solids non-fat and total solids yield (P<0.05). Dry matter intake and feed efficiency were not affected for dairy cows receiving AGB supplementation (P>0.05). The supplementation of mixed mineral-enriched essential oils (Agromix Booster®) at 0.5% of feed ration could improve milk yield but did not affect milk component content and feed efficiency of Holstein-Friesian dairy cows.

Keywords: Mineral, Essential Oils, Milk Production, Milk Quality, Feed Efficiency, Lactating Dairy Cows

Introduction

The local milk from Indonesia is not equivalent to the milk consumption demand. In 2020, Indonesia could only ful fill the 22.74% milk consumption criterion (BPS, 2021). Most cattle production comes from smallholder farms whose less attention to the feed ful fills the requirements of animals (Lestari *et al*., 2015). In contrast, dietary nutrition is essential in cattle development programs and the optimum manifestation of a dairy cow's genetic potential for milk production depends on appropriate nutritional availability (Bhanderi *et al*., 2016). In addition, animals require high-quality feed and sufficient amounts of vital minerals, and certain beneficial additives.

Micronutrients, most notably mineral elements, are necessary for animal systems' proper metabolic and physiological functions. Minerals are widely known for their regulatory functions in growth, production, and reproduction (Anam *et al*., 2021; Suttle, 2010). The use of mineral mixture in animal diets has also been shown to help in improving growth rates, feed efficiency, production of milk, reproduction performance, body immunities, minimizing the incidence of certain metabolic diseases, and reducing calving interval (Mohanta and Garg, 2014). For instance, Singh *et al*. (2016) found that dairy cows' providing a particular mineral combination improved milk production, especially during mid-lactation. Moreover, Madke *et al*. (2018) showed that lactating buffaloes fed mineral mixture have a greater the total milk production for 90 days and the dietary addition of mineral combination including Ca, P, Na, Cu, and Zn was effective in

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improving rumen parameters to sheep (Singh, 2015). Furthermore, dairy cows with macro and micro mineral deficits produced milk at a suboptimal level; but milk production levels increased after mineral supplementation (Sharma *et al*., 2002; 2003). Several mineral components also cannot be synthesized by organisms which different from the other nutrients. Minerals serve as fundamental elements of tissues and organs in the body, such as regulating the electrolyte systems and promoting enzyme and hormone systems in the body. The mineral elements' also most evident purpose is to provide the body's structural support (skeleton) (Sharma *et al*., 2002).

Moreover, among the various types of additives that have been extensively researched, essential oils are the most popular, owing to their remarkable effectiveness. The use of feed additives to manipulate rumen fermentation has been investigated extensively (Giannenas *et al*., 2011). Essential oils, as feed additives, have been shown to affect several rumen processes (Calsamiglia *et al*., 2007), including preventing amino acid deamination and reducing rumen methane generation (Greathead, 2003). As reported by Blanch *et al.* (2016), lactating dairy cows had milk production improvement when essential oils were supplemented on feed. The increase in energy-corrected milk and feed efficiency may be partly explained by changes in rumen fermentation when essential oils are supplemented (Elcoso *et al*., 2019).

Although many kinds of research have been performed to evaluate the effectiveness of single additives or particular mixes, there was a finite study when the mixed mineral containing macro and micro minerals are blended with essential oils. According to the above, it might be worthwhile to explore the inclusion of mixed mineral enhanced essential oils. Therefore, we hypothesized that feeding mixed mineral-enriched essential oils might positively affect dairy cows' milk production and feed efficiency. Accordingly, the objective of this study was to assess the impact of mixed mineral-enriched essential oils on lactation dairy cows' milk production and feed efficiency.

Materials and Methods

Location of Study

The experiment took place on a dairy farm, PT. Great Giant Livestock. The research area was located in Lampung Province of Indonesia on latitude -4.82958°N and longitude 105.26359°E.

Experimental Design and Procedure

Forty-eight lactating Holstein-Friesian cows with the Body Condition Score (BCS) of 3.45±0.58 and 187.08±21.53 Days In Milk (DIM) were used in this research. All animals were randomly assigned to two dietary treatments: An un-supplemented control group (CON; 24 cows) or a group that was supplemented with 0.5% top-up of Agromix Booster® (AGB; 24 cows) in Total Mix Ratio (TMR) for a total of 46 days. The Agromix Booster® consisted of mixed mineral calcium 243.4 g/kg, iron 12.5 g/kg, magnesium 1.8 g/kg, sodium 24.3 g/kg, phosphor 3.2 g/kg, manganese 1.2 g/kg, zinc 439.0 mg/kg, potassium 277.9 mg/kg, copper 179.4 mg/kg, sulphur 130.4 mg/kg, copper 5.4 mg/kg, selenium 131 µg/kg and blend essential oils (synthesized from eucalyptus, orange, lavender, soybeans, walnuts, sesame seeds and olives).

Table 1: Diet ingredients and chemical composition of the total mixed ration for dairy cows

Items	Value
Ingredients, % of dry matter	
Maize stover silage	38.00
Alfalfa hay	13.00
Soya full fat	4.50
Soya bean meal	7.00
Wheat bran	7.00
Distiller's dried grains with solubles	13.00
Corn	11.00
Molasses	4.00
Vitamin-mineral premix	2.50
Chemical composition, % of dry matter	
Dry matter	51.67
Organic matter	90.15
Crude protein	19.51
Crude fiber	15.31
Ether extract	4.77
Nitrogen-free extract	50.56

Table 2: Feed intake, milk production, milk component, and feed efficiency as affected by treatments

	Treatment[1]		
Items	CON	AGB	P-value[2]
BCS	3.44±10.33	3.46±00.82	0.903
DIM	185.17±19.63	189.00±23.54	0.543
DMI (kg/d)	20.12±10.32	20.18±10.41	0.843
Milk			
Yield (kg/d)	23.74±10.35[a]	24.46±10.54[b]	0.019
FCM (kg/d)	20.07±10.16	20.50±10.32	0.098
Milk component content			
Fat (%)	2.95±00.53	2.95±00.56	1.000
Protein (%)	3.28±00.75	3.26±00.58	0.733
Lactose (%)	5.10±00.16	4.80±00.25	0.154
Solid non-fat (%)	9.45±00.28	9.32±00.10	0.628
Total solid (%)	12.40±00.28	12.27±00.06	0.476
Milk component yield			
Fat (kg/d)	0.70±00.04	0.71±00.05	0.291
Protein (kg/d)	0.78±00.05	0.79±00.05	0.357
Lactose (kg/d)	1.19±00.08	1.18±00.07	0.654
Solid non-fat (kg/d)	2.21±00.14[a]	2.28±00.14[b]	0.018
Total solid (kg/d)	2.92±00.18[a]	3.00±00.19[b]	0.039
Feed efficiency			
kg milk/kg DMI	1.18±00.10	1.22±00.10	0.129
kg FCM/kg DMI	1.00±00.09	1.02±00.09	0.219

[1]CON = no supplementation, AGB = cows received 0.5% Agromix Booster® on diet
[2]Different letters (a-b) indicates significant difference ($p<0.05$) between two groups

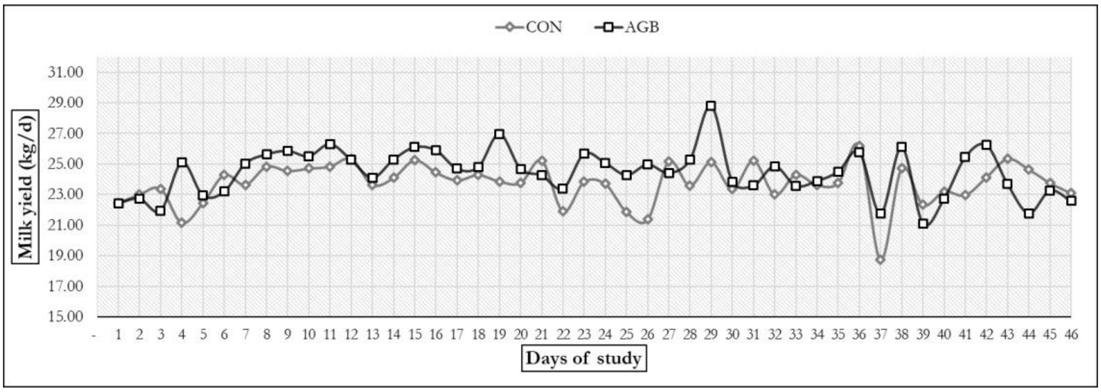

Fig. 1: Milk yield production of both two dietary treatments

Furthermore, each group of lactating dairy cows was kept in the free-stall barn. Animals were given the TMR as the basal diet and the component and nutrient values were shown in Table 1. Feed offered and refused was recorded daily, with refusals being maintained at 5% of the fresh intake to ensure ad libitum access to feed.

Measurements and Laboratory Analysis

Animals and housing facilities were examined twice daily, in the morning and afternoon, to assess general health, guarantee consistent feed and water availability and ensure appropriate temperature and ventilation. During the study period, the humidity and temperature scores were 87.7±3.81 and 27.01±0.99, respectively. The TMR was given to the cows twice daily and samples of TMR were obtained every three weeks and composited for subsequent analysis of nutrient content. The Dry Matter (DM) and Organic Matter (OM) content were determined by the gravimetric analysis (method 930.15, method 942.05) (AOAC, 2005), and the Crude Protein (CP) content was determined using Kjeldahl-nitrogen analysis (method 945.16) (AOAC, 2005), the Crude Fiber (CF) content was determined by using sequential acid and alkali extractions (method 978.10) (AOAC, 2005), the Ether Extract (EE) content was determined using Soxhlet extraction (method, 945.16) (AOAC, 2005) and Nitrogen-Free Extract (NFE) content was examined according to the equation reported by AOAC (2005). Feed consumption was determined by assessing the daily discrepancies between the quantity of feed given and the feed remaining every day during the study period. Consumption of Dry Matter Intake (DMI) was recorded.

All cows of each treatment were milked twice daily (morning and afternoon), using an automatic milk counter, and were totaled every day. The milk fat, protein, Solid Non-Fat (SNF), Total Solids (TS), and lactose as the milk qualities were measured using Lactoscan. The value of 4% Fat-Corrected Milk (FCM) was determined in accordance by NRC (2001), as follows: 4% FCM, kg/d = (0.4 × milk yield) + (15 × milk fat yield). The Feed Efficiency (FE) of milk yield was calculated as FE = milk yield (kg)/DMI (kg); FE of FCM yield was determined as FE = FCM (kg)/DMI (kg) (NRC, 2001).

Statistical Analysis

Collected data were analyzed by an Independent sample T-test using SPSS version 20 (SPSS Inc., Chicago, IL, USA), which mean differences were considered significant at $P<0.05$.

Results

As shown in Table 2, the DMI was not affected by AGB supplementation but the milk yield was significantly increased by AGB feeding. Furthermore, AGB supplementation also tended to increase the FCM ($P = 0.098$) (Table 2). In the AGB and CON groups, the milk fat content and yield, milk protein content and yield, milk lactose content and yield, milk SNF content and milk TS content were similar among the two groups. However, the milk SNF and milk TS yield were significantly increased in the AGB group (Table 2). The feed efficiencies, including milk yield/DMI and FCM/DM, were not affected for lactating dairy cows supplemented by AGB (Table 2). Moreover, the graphic of milk yield production during the study period was shown in Fig. 1.

Discussion

Dry Matter Intake

In this study, lactating dairy cows have supplemented a commercial mixed mineral-enriched essential oils (Agromix Booster®). Numerous macro-micro minerals and essential oils (spices and herbs) have been utilized to enhance animal growth and production (Braun *et al*., 2019; del Valle *et al*., 2015; Elcoso *et al*., 2019; Roshanzamir *et al*., 2020; Suksombat *et al*., 2017). In response to this feed additive, AGB supplementation did

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not affect DMI (Table 2). This finding was similar to Prayitno *et al*. (2016); the combination of mineral and garlic extract supplementation did not affect DMI in dairy cows. Sahoo *et al*. (2017) showed that the feed intake through concentrate and roughage was not influenced by mineral mixture supplementation, but there was an improvement in crude protein and extract ether digestibility. Another response; blend essential oils used on lactating dairy cows for 20 trial period showed no significant difference in DMI, but increased milk yield and FCM (Braun *et al*., 2019). Dairy cows supplemented by blend essential oils using commercial product Agolin Ruminat® also did not affect DMI (Elcoso *et al*., 2019). Moreover, lactating cows fed alfalfa combined with corn silage as a basal diet and added Crina Ruminants® supplementation showed no significant difference in DMI (Benchaar *et al*., 2007). However, several reports have explained that blend essential oils supplementation increased DMI, as a result by Kung *et al*. (2008) that blend essential oils supplementation significantly increased the DMI of dairy cows. The addition of blended essential oils (cinnamaldehyde-eugenol additive) consistently increased DMI on primiparous and multiparous cows in mid-lactation Wall *et al*. (2014). However, it is unknown how these chemicals impacts feed intake; nonetheless, some of these compounds may change palatability, thus affecting DMI. As need be, several variables may prompt varieties in the impact of essential oils on DMI, for example, essential oil provenance and proportions, variation of feed, and rumen microbial diversity (Geraci *et al*., 2012).

Milk Production

Supplementation of AGB significantly increased the milk yield but there was a tendency to increase FCM in the AGB group (P = 0.098) (Table 2). The current research results matched those of previous studies; Sahoo *et al.* (2017) showed that mineral mixture supplementation on lactating dairy cows was higher than 9.5% in milk yield and 11.8% in FCM compared to the control treatment. According to Roshanzamir *et al*. (2020), the addition of copper, manganese, and zinc to lactating dairy cows increased milk production substantially. Supplementing zinc, manganese and copper also improved the milk yield of lactating dairy cows (36.8 kg/d) compared to the control diet (35.7 kg/d) (Kellogg and Johnson, 2003). According to Somkuwar *et al*. (2011), milk production dropped by 0.38 liters after an observation period when dairy cows were not given minerals, but animals received inorganic and organic minerals and milk yield increased by 0.2 and 0.64 liters, respectively. The role of trace minerals in the formation of protein structures, enzymes, and hormones may cause increased milk production (Suttle, 2010).

Additionally, lactating cows fed a diet containing essential oils produced substantially more milk and higher FCM (Braun *et al*., 2019). Cows given a blend of essential oils supplemented meals produced much more milk compare to the un-supplemented cows (Kung *et al*., 2008; Tassoul and Shaver, 2009). Milk yield production from supplemented dairy cows with commercial blend essential oils (500 mg/kg DM) also increased (Ferreira de Jesus *et al*., 2016). The increased milk production with blended essential oils addition correlated with the fermentation process in the rumen (Calsamiglia *et al*., 2007; Harmini *et al*., 2020). In ruminal fermentation, blended essential oils promote the lowering ratio of acetate and propionate, resulting in reduced methane energy production (Calsamiglia *et al*., 2007; Juniper *et al*., 2006). Additionally, blended essential oils were also attributed to endocrine stimulation (Tager and Krause, 2011), which improved the nutrients transferred to the mammary gland and glucocorticoids from the body (Serbester *et al*., 2012).

Milk Component Content and Yield

AGB supplementation did not affect the milk contents, including milk fat, protein, lactose, SNF, and TS. Moreover, there were no significant differences also in fat, protein, and lactose yield, but SNF and TS yield were significantly increased in the AGB group (Table 2). Singh *et al*. (2016) showed that there were non-significant differences in the percentages of milk fat, protein, lactose, and SNF after the mineral mixture was added to lactating dairy cows and buffaloes for 30 days. Harmini *et al*. (2020) examined the several diets containing various minerals; and reported no changes in protein, fat, lactose, and SNF, but there were significant differences in milk mineral content (Fe and Mg). Sahoo *et al*. (2017) also added that mineral mixture supplementation did not affect the milk protein and SNF percentage of cows. Moreover, Se supplementation on feed did not influence milk components, including fat, protein, and lactose (Juniper *et al*., 2006). Blend essential oils supplementation also showed no differences in milk content (Flores *et al*., 2013; Serbester *et al*., 2012; Tager and Krause, 2011). We considered that the milk content was greatly affected by feed consumption, primarily forage as a fiber source (Prayitno *et al*., 2016). In this study, the SNF and TS yields were increased in the AGB group. Prayitno *et al*. (2016) also showed that the supplementation of minerals and garlic extract increased the SNF yield, even though SNF percentages in milk were similar among the treatment. It might be caused that yields for SNF and TS positively correlated to milk products. However, in this research, the milk content met the standard requirement of the Indonesian national standard (NSAI, 2011).

Feed Efficiency

According to Table 2, the feed efficiencies, including milk yield/DMI and FCM/DMI were not affected for dairy cows receiving AGB supplementation. However, results regarding the effects of feed additives on feed efficiency are inconsistent in the literature. Joch *et al*. (2019) reported that supplementing blend essential oils on long-period treatment did not affect feed efficiency and tended to decline over time. Elcoso *et al*. (2019) showed that feed efficiency evolved differently over time, with cows fed Agolin Ruminat® becoming more efficient after the fourth week of the study, reaching significant differences after 6 and 8 weeks. Kung *et al*. (2008) discovered a significant increase in milk yield and DMI, but feed efficiency (FCM/DMI) was similar among the two treatments. On the other hand, some studies using other various essential oils or plant extracts have shown increases in feed efficiency. According to Tassoul and Shaver (2009), feed efficiency (milk yield/DMI) was higher for essential oils than control on average and was higher during lactation on weeks 8 to 14. In a study by Braun *et al*. (2019), feed efficiency (FCM/DMI) significantly increased with blend essential oils supplementation. Al-Suwaiegh *et al*. (2020) showed that supplementing blend essential oils, 25 g/day to the diet of early lactation cows, increased feed efficiency compared with the control group, 1.31 vs. 1.24 milk yield/DMI, respectively. The differences in feed efficiency responses may be related to the lactation stage, the kind and combination of plant extracts, or the dosages used.

Conclusion

The supplementation of mixed mineral-enriched essential oils (Agromix Booster®) at 0.5% of feed ration could improve milk yield but did not affect milk component content and feed efficiency of Holstein-Friesian dairy cows.

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Author's Contributions

Mohammad Sofi'ul Anam and Ali Agus: Designed, analyzed the data, and prepared the first manuscript.

Andriyani Astuti and Budi Prasetyo Widyobroto: Laboratory analyzed and reviewed the manuscript.

Surya Retnaningrum: Conducted the research and prepared data tabulation.

Ethics

This article is original, has no ethical issues, and was not published elsewhere. The corresponding author confirmed that all authors have read and approved the final manuscript.

References

Al-Suwaiegh, S. B., Morshedy, S. A., Mansour, A. T., Ahmed, M. H., Zahran, S. M., Alnemr, T. M., & Sallam, S. M. A. (2020). Effect of an essential oil blend on dairy cow performance during treatment and post-treatment periods. Sustainability (Switzerland), 12(21), 1-16. doi.org/10.3390/su12219123

Anam, M. S., Agus, A., Yusiati, L. M., Hanim, C., Astuti, A., Bintara, S., & Al Anas, M. (2021). Blood biochemical profiles and pregnancy rate of brahman crossbred cows supplemented with the mineral mixture. American Journal of Animal and Veterinary Sciences, 16(3), 176–184. doi.org/10.3844/ajavsp.2021.176.184

AOAC. (2005). Official Methods of Analysis (18th ed.). Association of Official Analytical Chemists.

Benchaar, C., Petit, H. V., Berthiaume, R., Ouellet, D. R., Chiquette, J., & Chouinardt, P. Y. (2007). Effects of essential oils on digestion, ruminai fermentation, rumen microbial populations, milk production and milk composition in dairy cows fed alfalfa silage or corn silage. Journal of Dairy Science, 90(2), 886–897. doi.org/10.3168/jds.S0022-0302(07)71572-2

Bhanderi, B. M., Goswami, A., Garg, M. R., & Samanta, S. (2016). Study on minerals status of dairy cows and their supplementation through area-specific mineral mixture in the state of Jharkhand. Journal of Animal Science and Technology, 58(1), 1–8. doi.org/10.1186/s40781-016-0124-2

Blanch, M., Carro, M. D., Ranilla, M. J., Viso, A., Vázquez-Añón, M., & Bach, A. (2016). Influence of a mixture of cinnamaldehyde and garlic oil on rumen fermentation, feeding behavior and performance of lactating dairy cows. Animal Feed Science and Technology, 219, 313–323. doi.org/10.1016/j.anifeedsci.2016.07.002

BPS. (2021). Produksi Susu Perusahaan Sapi Perah 2018-2020. https://www.bps.go.id/indicator/24/376/1/produksi-susu-perusahaan-sapi-perah.html

Braun, H. S., Schrapers, K. T., Mahlkow-Nerge, K., Stumpff, F., & Rosendahl, J. (2019). Dietary supplementation of essential oils in dairy cows: Evidence for stimulatory effects on nutrient absorption. Animal, 13(3), 518–523. doi.org/10.1017/S1751731118001696

NSAI. (2011). Fresh Milk-Part 1: Cow. Standard Nasional Indonesia (National Standardization Agency of Indonesia) BSN. No. 3141.

Calsamiglia, S., Busquet, M., Cardozo, P. W., Castillejos, L., & Ferret, A. (2007). Invited review: Essential oils as modifiers of rumen microbial fermentation. Journal of Dairy Science, 90(6), 2580–2595. doi.org/10.3168/jds.2006-644 del Valle, T. A., de Jesus, E. F., de Paiva, P. G., Bettero, V. P., Zanferari, F., Acedo, T. S., Tamassia, L. F. M., & Rennó, F. P. (2015). Effect of organic sources of minerals on fat-corrected milk yield of dairy cows in confinement. Revista Brasileira de Zootecnia, 44(3), 103–108. doi.org/10.1590/S1806-92902015000300004

Elcoso, G., Zweifel, B., & Bach, A. (2019). Effects of a blend of essential oils on milk yield and feed efficiency of lactating dairy cows. Applied Animal Science, 35(3), 304–311. doi.org/10.15232/aas.2018-01825

Ferreira de Jesus, E., Del Valle, T. A., Calomeni, G. D., Silva, T. H., Takiya, C. S., Vendramini, T. H. A., Paiva, P. G., Silva, G. G., Netto, A. S., & Rennó, F. P. (2016). Influence of a blend of functional oils or monensin on nutrient intake and digestibility, ruminal fermentation and milk production of dairy cows. Animal Feed Science and Technology, 219, 59–67. doi.org/10.1016/j.anifeedsci.2016.06.003

Flores, A. J., Garciarena, A. D., Hernández Vieyra, J. M., Beauchemin, K. A., & Colombatto, D. (2013). Effects of specific essential oil compounds on the ruminal environment, milk production and milk composition of lactating dairy cows at pasture. Animal Feed Science and Technology, 186(1–2), 20–26. doi.org/10.1016/j.anifeedsci.2013.09.001

Geraci, J. I., Garciarena, A. D., Gagliostro, G. A., Beauchemin, K. A., & Colombatto, D. (2012). Plant extracts containing cinnamaldehyde, eugenol and capsicum oleoresin added to feedlot cattle diets: Ruminal environment, short-term intake pattern and animal performance. Animal Feed Science and Technology, 176(1–4), 123–130. doi.org/10.1016/j.anifeedsci.2012.07.015

Giannenas, I., Skoufos, J., Giannakopoulos, C., Wiemann, M., Gortzi, O., Lalas, S., & Kyriazakis, I. (2011). Effects of essential oils on milk production, milk composition and rumen microbiota in Chios dairy ewes. Journal of Dairy Science, 94(11), 5569–5577. doi.org/10.3168/jds.2010-4096

Greathead, H. (2003). Plants and plant extracts for improving animal productivity. Proceedings of the Nutrition Society, 62(2), 279–290. doi.org/10.1079/pns2002197

Harmini, H., Evvyernie, D., Karti, P. D. M. H., & Widiawati, Y. (2020). Evaluation of Mineral Contents in Milk of Dairy Cattle Fed Elephant Grass Planted at Ex-Coal Mining Land. Tropical Animal Science Journal, 43(4), 322–330. doi.org/10.5398/tasj.2020.43.4.322

Joch, M., Kudrna, V., Hakl, J., Božik, M., Homolka, P., Illek, J., Tyrolová, Y., & Výborná, A. (2019). In vitro and in vivo potential of a blend of essential oil compounds to improve rumen fermentation and performance of dairy cows. Animal Feed Science and Technology, 251(September 2018), 176–186. doi.org/10.1016/j.anifeedsci.2019.03.009

Juniper, D. T., Phipps, R. H., Jones, A. K., & Bertin, G. (2006). Selenium supplementation of lactating dairy cows: Effect on selenium concentration in blood, milk, urine, and feces. Journal of Dairy Science, 89(9), 3544-3551. doi.org/10.3168/jds.S0022-0302(06)72394-3

Kellogg, D. W., & Johnson, Z. B. (2003). Arkansas # Animal Science # Department Report 2003. Agriculture, 1, 169. http://www.uark.edu/depts/agripub/Publications/researchseries/

Kung, L., Williams, P., Schmidt, R. J., & Hu, W. (2008). A blend of essential plant oils is used as an additive to alter silage fermentation or used as a feed additive for lactating dairy cows. Journal of Dairy Science, 91(12), 4793–4800. doi.org/10.3168/jds.2008-1402

Lestari, D. A., Abdullah, L., & Despal. (2015). Comparative study of milk production and feed efficiency based on farmer's best practices and national research council. Media Peternakan, 38(2), 110–117. doi.org/10.5398/medpet.2015.38.2.110

Madke, P. K., Pal, D., Prakash, S., & Kumar, A. (2018). Effect of mineral mixture feeding on milk yield in buffalo. Research Journal of Animal Husbandry and Dairy Science, 9(2), 42–44. doi.org/10.15740/has/rjahds/9.2/42-44

Mohanta, R., & Garg, A. (2014). Organic Trace Minerals: Immunity, Health, Production and Reproduction in Farm Animals. Indian Journal of Animal Nutrition, 31(3), 203–212.

NRC. (2001). Nutrient Requirements of Dairy Cattle. In Nutrient Requirements of Dairy Cattle (Seventh). The National Academy Press. doi.org/10.17226/9825

Prayitno, C. H., Suwarno, Susanto, A., & Jayanegara, A. (2016). Effect of garlic extract and organic mineral supplementation on feed intake, digestibility and milk yield of lactating dairy cows. Asian Journal of Animal Sciences, 10(3), 214–218. doi.org/10.3923/ajas.2016.213.218

Roshanzamir, H., Rezaei, J., & Fazaeli, H. (2020). Colostrum and milk performance and blood immunity indices and minerals of Holstein cows receiving organic Mn, Zn and Cu sources. Animal Nutrition, 6(1), 61–68. doi.org/10.1016/j.aninu.2019.08.003

Sahoo, B., Kumar, R., Garg, A. K., Mohanta, R. K., Agarwal, A., & Sharma, A. K. (2017). Effect of Supplementing Area Specific Mineral Mixture on Productive Performance of Crossbred Cows. Indian Journal of Animal Nutrition, 34(4), 414. doi.org/10.5958/2231-6744.2017.00066.4

Serbester, U., Çinar, M., Ceyhan, A., Erdem, H., Görgülü, M., Kutlu, H. R., Çelik, L. B., Yücelt, O., & Cardozo, P. W. (2012). Effect of essential oil combination on performance, milk composition, blood parameters and pregnancy rate in early lactating dairy cows during heat exposure. Journal of Animal and Plant Sciences, 22(3), 556–563.

Sharma, M. C., Joshi, C., & Sarkar, T. K. (2002). Therapeutic efficacy of minerals supplements in macro-minerals deficient buffaloes and its effect on haemato biochemical profile and production. Asian-Australasian Journal of Animal Sciences, 15(9), 1278–1287. doi.org/10.5713/ajas.2002.1278

Sharma, M. C., Raju, S., Joshi, C., Kaur, H., & Varshney, V. P. (2003). Studies on serum micro-mineral, hormone and vitamin profile and its effect on production and therapeutic management of buffaloes in the Haryana State of India. Asian-Australasian Journal of Animal Sciences, 16(4), 519–528. doi.org/10.5713/ajas.2003.519

Singh, Shivdeep, Chhabra, S., Singh, C., Randhawa, S., & Gupta, D. (2016). Effect of Area Specific Mineral Mixture Feeding on Milk Yield and Composition of Dairy Animals of Central Zone of Punjab. International Journal of Livestock Research, 6(3), 62. doi.org/10.5455/ijlr.20160326103223

Singh, Shweta. (2015). UKnowledge Effect of Mineral Supplementation on Rumen Metabolites and Enzymes in Sheep Fed Sorghum Stover Based Diets.

Somkuwar, A. P., Kadam, A. S., Kumar, S., & Radhakrishna, P. M. (2011). Efficacy Study of Metho-Chelated Organic Minerals preparation Feeding on Milk Production and Fat Percentage in dairy cows. Veterinary World, 4(1), 19–21. doi.org/10.5455/vetworld.2011.19-21

Suksombat, W., Nanon, A., Meeprom, C., & Lounglawan, P. (2017). Feed degradability, rumen fermentation, and blood metabolites in response to essential oil addition to fistulated non-lactating dairy cow diets. Animal Science Journal, 88(9), 1346–1351. doi.org/10.1111/asj.12778

Suttle, N. V. (2010). Mineral Nutrition of Livestock (4th ed.). CAB International Pubslihing.

Tager, L. R., & Krause, K. M. (2011). Effects of essential oils on rumen fermentation, milk production and feeding behavior in lactating dairy cows. Journal of Dairy Science, 94(5), 2455–2464. doi.org/10.3168/jds.2010-3505

Tassoul, M. D., & Shaver, R. D. (2009). Effect of a mixture of supplemental dietary plant essential oils on the performance of periparturient and early lactation dairy cows. Journal of Dairy Science, 92(4), 1734–1740. doi.org/10.3168/jds.2008-1760

Wall, E. H., Doane, P. H., Donkin, S. S., & Bravo, D. (2014). The effects of supplementation with a blend of cinnamaldehyde and eugenol on feed intake and milk production of dairy cows. Journal of Dairy Science, 97(9), 5709–5717. doi.org/10.3168/jds.2014-7896