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Effects of dietary chromium-yeast level on feed digestibility and growth Performance of goats

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Abstract
The study was conducted to determine the effect of giving feed supplements in the form of Chromium-yeast minerals on consumption, feed digestibility, rumen metabolite products, daily body weight gain (ADG) and body condition score (BCS). The research was conducted at Gunung Tugel Farm, Banyumas, Central Java, Indonesia. The material used was 24 male Jawarandu goats with an average initial weight of 25 ± 1,23 kg, individual cages, the feed given consisted of elephant grass silage and concentrate. The treatment feed contains chromium-yeast at levels of 0; 0,5; 1; and 1,5 mg/kg. The research method used was experimental using a completely randomized design. There were 4 treatments tested, namely T0 (70% concentrate + 30% elephant grass silage), T1 (70% concentrate + 30% elephant grass silage + 0,5 mg/kg chromium -yeast), T2 (70% concentrate + 30% elephant grass silage + 1 mg/kg chromium-yeast) and T3 (70% concentrate + 30% elephant grass silage + 1,5 mg/kg chromium-yeast). Each treatment was repeated 6 times so there were 24 trials. The further test used is polynomial orthogonal. The variables measured in this study were feed consumption, feed digestibility, rumen metabolite products, daily body weight gain and body condition score. The results of the analysis of variance showed that the treatment had a significant effect on dry material and organic material consumption, feed digestibility, VFA, N-NH3, blood glucose, and had a very significant effect on ADG (average daily gain) and BCS (body condition score). In conclusion, chromium-yeast supplementation was able to improve goat performance with optimal levels ranging from 1,04 – 1,36 mg/kg of feed.

Keywords: Body condition score, Chromium-yeast, daily gain, goat

INTRODUCTION

Chromium (Cr) was an essential micronutrient. This mineral was an integral part of Gluco tolerance Factor (GTF) which increases the adhesion of insulin to the cell membrane surface and allows the entry of glucose, fatty acids and amino acids into cells (Mertz 1969; Anderson 1998), due to the binding of these (chromodulin) to the insulin receptor transmembrane (Evans and Bowman 1992) specifically to the a subunit, converting it to autokinase via phosphorylation of the b subunit (Vincent 2013). Although Cr was essential for insulin function and efficient nutrient metabolism (Mertz 1993) in humans and livestock, consumption of Cr in feed was often less than the recommended dose (0,2 mg Cr/kg DM) (Anderson 1998; National Research Council 2005).

Growth hormone (GH) and insulin growth factor (IGF) were involved in Cr metabolism (Mowat 1997); in ruminants, Cr has an impact on growth (Kegley et al. 1997; Haldar et al. 2007), Cr increased the response capacity of the immune system (Haldar et al. 2009); In poultry and swine, Cr supplementation had a better positive effect on metabolic responses, nutrient distribution and carcass characteristics, possibly due to increased sensitivity to insulin and glucose utilization efficiency (Mohanty et al., 2022). The degree of this effect was depend on the dietary intake, as well as the chemical form and concentration of Cr (Galip 2006; Yan et al. 2008; Dom_ınguez-Vara et al. 2009; Arvizu et al. 2011). The trivalent form of Cr cannot pass the cell membrane, hence its activation requires attachment to a ligand (Burton 1995); also some inorganic forms of Cr were not available for uptake (Mordenti et al. 1997) whereas organic sources were more bioavailable. In sheep and cattle administration rates of 0,2–1,2 mg Cr/kg DM have been tested and doses equal to or greater than 0,35 mg Cr/kg DM has an effect primarily on blood glucose levels. As such, positive effects such as increased growth of lean tissue in ruminants, may be expected from using Cr-enriched yeast. There seems a lack of knowledge on the effects of Cr-yeast on goat fattening, hence further study is required. The aim of this study was to evaluate the effect of high concentrations of Cr-enriched yeast added at different levels in a high-energy diet fed to fattening goats on growth performance.

MATERIALS AND METHODS

The material used was twenty-four male Jawarandu goats aged 8-10 months (25 ± 0,17 kg), the goats were dewormed, multivitamins and placed in individual cages (1,5 x 1,2 m) for an adaptation period of 15 days . Goats were fed basal feed (BF) (Table 1) formulated according to the requirements of finishing goats (National Research Council 2007). The basic feed given was recorded every day and feed samples were taken every week, dried at 55 ˚C for 48 hours to determine the chemical composition (Table 1). Nutrient content was determined by the AOAC method (2012), dry material (method 967.03), ash (method 942.05) and crude protein (Kjeldahl procedure, method 976.06, N_6.25), metabolic energy was calculated based on composition of feed ingredients (National Research Council 2007). Chromium was given every day and mixed with feed which was served at 08.00. Feed was given ad libitum twice at 08.00 and 16.00. The feed given was recorded every day. Body weight was recorded at the start of fattening and every two weeksduring maintenance. On days 14, 35, 49, 63, 77, and 91, three hours after the morning feeding, blood samples (7 mL) were collected from the jugular vein in a vacutainer tube with potassium oxalate. Blood samples were centrifuged and stored at -20 ˚C to glucose analysis (Kitchalong et al. 1995) with semi-automated equipment. (Vitros DT60II-Johnson and Johnson Co.). Rumen fluid was collected by ribs between 3 and 4 by a veterinarian 4 hours after feeding at the end of the study period.

To ensure consumption of the planned dose, the total daily dose of Cr from each treatment was mixed with 30 g of rejected bread flour and given in the morning using individual feeds. The experiment lasted 105 days. Goats were weighed one by one in the morning (07.00) before feeding.

The research design used was a completely randomized design (CRD) with 4 treatments and 6 replications so there were 24 experimental units. The treatment in this study were:

T0 = basal feed (70% concentrate + 30% elephant grass silage, 15,33% CP and 69,44% TDN)
T1 = T0 + 0,5 mg/kg chromium-yeast
T2 = T0 + 1 mg/kg chromium-yeast
T3 = T0 + 1,5 mg of chromium-yeast

Goats were given feed 4,5% of body weight. Basal feed formulations were presented in Table 1.

Table 1. Nutrient Level of Basal Feed

Feedstuff	g/1000 g DM
Wheat Pollard	308
Rice hull	37,8
seaweed	25,2
Palm oil meal	105
Soybean Meal	21
Coconut meal	105
CGF	77
Soya shell	35
mineral mix	10,5
Salt	7
Dolomites	3,5
Kinggrass Silage	300
Nutrients :	
DM (%)	67,12
Ash (%)	19,94
Crude Fiber (%)	20.76
Crude Protein (%)	15,06
TDN (%)	66,74
Ca (%)	0,6
Phosphor(%)	0,4

Parameter Measurement :

Daily body weight gain was obtained by weighing the animals every 2 weeks during the investigation period from the beginning to the end of the study before the animals were given feed. The final result of ADG was obtained by the difference between the final weight minus the initial weight then divided by the length of maintenance expressed in units of grams/head/day. The formula that was utilized could be explained as follows:

$$\text{ADG} = \frac{\text{Final weight(g)} - \text{Initial weight(g)}}{\text{Days(D)}} = \text{g/head/day}$$

Assessment of the body condition score (BCS) was carried out by the palpation method and observations were made by 3 people as raters. The BCS assessment was carried out by touching the back, base of the tail and hips which were then compared with the BCS table to find out the value.

RESULTS AND DISCUSSION

The results of this study showed that Chomium yeast supplementation has an effect on the consumption of dry material and organic material. The consumption value of dry material and organic material was highest in the supplementation of 1 mg/kg dry material. The results of this study indicated that in the T2 treatment where Jawarandu goats were given basal feed supplemented with 1,0 mg/kg of chromium-yeast mineral, it was able to produce the highest average value of dry material and organic material consumption, namely 1130,23 ± 121,38 g/head/day and 542,28 ± 58,03 g/head/day compared to treatment T0, T1, and T3. The results of this study have lower average consumption of dry material and organic material compared to the Moreno-Camarena et al. (2020) who conducted a study adding Chromium yeast up to 0,6 mg Cr-yeast.

Other researchers who conducted research on sheep showed that Chromium-methionine supplementation of up to 3 mg/kg would reduce feed consumption (Seifalinab et al., 2022), while Kargar et al. (2018) highlight increased feed consumption with chromium supplementation in Holstein male calves. Dry material consumption was the difference between the dry material level of the feed given and the dry material level of the rest of the feed, so that the dry material consumption of livestock was strongly influenced by the dry material level of the feed. Consumption of dry material may also be influenced by the crude fiber level in the ration. The high level of crude fiber in the feed would be difficult to be degraded by rumen microbes so that it has an impact on the digestibility of the feed.

Table 2. Effect of treatment on consumption of dry material, organic material, crude protein and crude fiber

Variables	Level of Cr-yeast (ppm)				P-value
	T0 (0)	T1 (0,5mg/kg)	T2 (1,0 mg/kg)	T3(1,5mg/kg)	
DMI (g/d)	1014.47 ± 47.30^{ab}	918.00 ± 99.31^{a}	1130.23 ± 121.38^{b}	1010.28 ± 78.52^{ab}	0.017
DMI/BW (%)	2.99	2.68	3.07	2.88	
OMI g/d	486.98 ± 23.61^{ab}	440.55 ± 46.49^{a}	542.28 ± 58.03^{b}	485.35 ± 37.74^{ab}	0.016
OMI/BW (%)	1.44	1.29	1.47	1.38	
CPI (g/d)	141.67±12.43	157.79±20.85	167.90±21.33	157.80±17.68	0.199
CFI (g/d)	183.84±19.36	196.24±23.77	217.93±29.03	188.07±19.71	0.138

Meanwhile, the consumption of protein and crude fiber in all treatments with the addition of Chromium-yeast showed the same results, which ranged from 141.67 ± 12.43 g/d (T0) to 167.90 ± 21.33 g/d (T2) on protein consumption and 183.84 ± 19.36 g/d to 217.93 ± 29.03 g/d on crude fiber consumption. Even though the effect was not statistically significant, there was a similar trend with the consumption of DMI and OMI in that the T2 treatment (addition of 1 mg/kg) showed the highest consumption of protein and crude fiber.

Feed containing chromium could increase the fermentation of the ration in the rumen because chromium was an essential mineral for the growth, performance and population of rumen microbes so that the fermentability in the rumen increases (Prayitno et al., 2013; Jayanegara et al., 2006; Setyaningrum et al., 2022).

Based on the average value of the digestibility of dry material and organic material in Table 3, it showed that the treatment has a significant effect on the digestibility of dry material and organic material. The results of this study indicated that in the 1,0 mg Chromium-yeast supplementation treatment where Jawarandu goats were given basal feed supplemented with organic chromium mineral 1,0 mg/kg of feed was able to produce the highest average digestibility of dry material and organic material, namely 76.56 ± 2.69% and 76,83 ± 2.84,% compared to the 0, 0.5, and 1.5 mg/kg Chromium-yeast treatments. Digestibility of dry material was the difference between the amount of dry material consumption minus the dry material of faeces divided by the amount of dry material consumption multiplied by one hundred percent, while the digestibility of organic material was the difference between the amount of consumption of organic material minus the organic material of faeces divided by the amount of organic material consumption multiplied by one hundred percent.

Table 3. The effect of treatment on the digestibility of DM, OM, CP and crude fiber

Variables	Level of Cr-yeast (ppm)				P-value
	T0 (0)	T1 (0,5mg/kg)	T2 (1,0 mg/kg)	T3(1,5mg/kg)	
DMD (%)	75.37 ± 2.90[ab]	71.07 ± 1.47[a]	76.56 ± 2.69[b]	73.21 ± 2.63[ab]	0.015
OMD (%)	75.69 ± 3.44[ab]	71.21 ± 1.59[a]	76.83 ± 2.84[b]	73.00 ± 2.38[ab]	0.022
CPD (%)	82.88±2.34	80.48±3.21	83.98±2.62	82.02±2.51	0.251
CFDs (%)	59.72±6.01	57.20±4.51	66.43±5.18	58.96±4.96	0.360

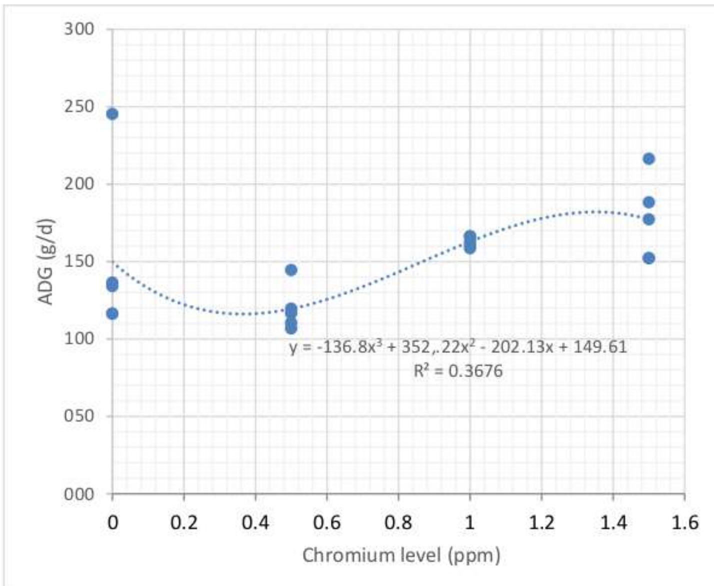
The results indicated that chromium-yeast supplementation has an effect on daily gain, BCS, VFA, N-NH3 and blood glucose. Chromium as a glucose tolerance factor (GTF) was able to stimulate the hormone insulin to carry glucose to target organs. It was characterized by the rise and fall of glucose concentrations. Chromium yeast supplementation increased the concentration of total Volatile Fatty Acids (VFA). VFA was the main source of energy in ruminants, thus increase in VFA has a positive impact on growth. Cr-Yeast supplementation 1,0 mg/kg – 1,5 mg/kg gives the most response on daily gain. It was believed that the availability of energy in the form of VFA was also balanced with the optimal availability of N sources (in the form of N-NH3). The fatty acid component of VFA which greatly influences growth was propionic acid. Propionic acid has glucogenic properties which in the liver would be converted into blood glucose. Blood glucose would enter the cells and be used to support the body's fat and protein synthesis as well as a source of ATP (McDonald et al., 2002). The function of organic chromium added to the feed may help speed up the process of glucose transportation in the livestock body. Organic chromium could increase the activity potential of the insulin hormone which plays an important role in the transport of glucose and amino acids. Increased use of glucose by insulin would then be used by livestock for organ formation, namely the formation of muscle and adipose tissue.

Table 4. Effect of Treatment on ADG, BCS, VFA, N-NH3 and Glucose

Variables	Level of Cr-yeast (ppm)				P-value
	T1 (0)	T1 (0,5mg/kg)	T2 (1,0 mg/kg)	T3(1,5mg/kg)	
ADG (g/d)	131.53 ± 10,48[a]	119.19 ± 16.57[a]	162.65 ± 3.76[b]	177.19 ± 20,78[b]	0.000207
BCS	2.5 ± 0,24[a]	2.8 ± 0.16[ab]	2.61 ± 0.18[a]	3.0 ± 0.22[bc]	0.01954
VFA (mMol)	73.2±4.72	86.0±9.57	97.4±12.81	99.6±13.15	0.002

N-NH3 (mMol)	27.68±1.5	28.72±1.1	27.08±1.67	30.14±1.98	0.09
Glucose (mg/dL)	57.60±8.12	63.43±12.39	60.57±11.36	54.29±8.48	0.067

Figure 1. Average Daily Result



Based on the polynomial orthogonal further test results that the use of chromium levels to produce the maximum ADG was achieved at the level of 1,36 mg/kg. Using chromium at this level results in ADG which was at the top of the curve (Figure 1). The high ADG of goats was supported by the age of the goats used. Goats used as research material have ages ranging from 8-10 months, at this age there was rapid growth, before sexual maturity and slow growth occurs when the body was mature.

The high ADG in the T3 treatment, which was 177,19 ± 20,78 g/head/day, was due to the provision of good quality feed. The feed given was in the form of 30% forage and 70% concentrate. The feed produced a CP of 15,33% and a TDN of 69,44%. Based on the SNI table for fattening goat feed, the feed given was according to the standard. The high ADG results was supported by chromium-yeast supplementation at a level of 1,5 mg/kg feed. Giving chromium-yeast in the feed would accelerate the digestibility of the feed so that the absorption of feed nutrients for the formation of meat becames more optimal. The use of Cr-yeast was thought to increase the proportion of propionate. Jayanegara (2006) reported that the addition of organic chromium increased the production of NH3, total VFA and the proportion of propionate in the rumen. Propionic acid has glucogenic properties which in the liver would be converted into blood glucose. In this case, blood glucose would enter the cells and be utilized to support the body's fat and protein synthesis as well as a source of ATP (McDonald et al., 2002). The function of chromium added to the feed may help speed up the process of glucose transportation in the livestock body. Chromium-yeast could increase the activity potential of the insulin hormone which contributted in the transport of glucose and amino acids. Increased use of glucose by insulin would be used by livestock for tissue formation, namely the formation of muscle and adipose tissue (Estrada-Angulo et al., 2013, Setyaningrum et al., 2022).

The results of this study also indicated that the treatment given has a very significant effect on the goat's BCS. The highest BCS was achieved in the T3 treatment which was 3,00 ± 0,19. This is was when compared to the study of Ahriza et al (2020), which has a BCS of 2,64 ± 0,37. These results highlight that the study goats showed ideal body conditions. The ideal BCS indicated that the feed given was of good quality and the management applied was appropriate. The lowest BCS value was achieved in the T0 treatment with an average of 2,5 ± 0,24. This indicated that the T0 feed in the form of elephant grass silage + concentrate has not been able to increase BCS to the fullest. However, this figure was still within the normal/ideal BCS range. BCS value in the T1 treatment (2,8 ± 0,26) higher than the T2 treatment (2,6 ± 0,15). However, this was inversely proportional to the ADG. Treatment on T2 resulted in greater ADG than T1 (162,89 ± 3,87 vs 119,50 ± 17,12). The difference in BCS was caused by many factors, one of which was age. According to Ghosh et al (2019), as goats get older, goats may lose body fat quickly. This was in line with the fact that the goats used as research material had ages in the range of 8-10 months. The BCS value in the T2 treatment (1 mg/kg) was lower than the T1 treatment (0,5 mg/kg) which may also be suspected because of the lower fat level in T2 goats.

The mean values of BCS T0, T1 and T2 were in the range of 2,5. This figure was still within the normal range and gets the ideal predicate. Visualization that appears in goats was a slightly bony appearance, the backbone was quite visible, the spinous bones look slightly protruding and one third of the transverse bones were visible. When palpating, the transverse bones could be easily felt by the fingers with pressure. The ribs could be felt, the intercostal spaces were smooth but permeable, the muscle areas were of moderate depth and little overlying fat. Factors that affects the BCS of goats include genetics, feed, and applied management.

The mean value of the BCS T3 treatment would be the pressure required to feel the spine. The transverse and spinous bones may be felt by the fingers and there was moderate muscle and fat tissue when pressure was applied. The visual appearance of the goat was somewhat rounded, the spine was not very prominent, the ribs were not clearly visible and the intercostal space could still be felt with a little pressure. Based on the results of the BCS assessment, goats in the T3 treatment received an average rating.

Based on Table 4, treatment T0 where goats were fed basal diet without Chromium resulted in total VFA levels with an average lower than normal levels, namely below 80 mM, whereas in treatments T1, T2, and T3 where goats were given feed supplemented with organic Chromium produced higher levels Total VFA with an average that was within normal levels, namely between 80-160 mM. These results showed that in this study goats fed organic Chromium had normal and higher total VFA levels compared to goats not given organic Chromium. This was in accordance with the research of Jayanegara et al. (2006) that Chromium supplementation in both inorganic and organic forms resulted in total VFA production within the optimal and proper range for the survival of ruminants, namely between 80 – 160 mM.

Normal total VFA levels in goats given Chromium-yeast at T1, T2, and T3 with successive doses of 0,5 mg/kg, 1,0 mg/kg and 1,5 mg/kg indicated that the administration of Chromium- Yeast at this dose was safe for the feed fermentation process by rumen microbes. Normal VFA (Volatile Fatty Acids) levels indicated that the feed fermentation process that occurs in the rumen was going well (Sutaryo et al., 2019). This was supported by statements by Prayitno et al. (2014) that the better the growth of rumen microbes may cause the population of carbohydrates digesting microbes to be higher, this causes the process of carbohydrate fermentation in the rumen to run better.

N-NH3 or ammonia in the rumen fluid was the result of the degradation process of protein and non-protein nitrogen (NPN) in the rumen which play a role in the synthesis of rumen microbial protein. N-NH3 was used by rumen microbes as the main source of nitrogen (N) to synthesize protein. The concentration of N-NH3 in the rumen was an indicator to determine feed fermentability which was related to feed protein digestibility, activity and rumen microbial population. Based on the results of all treatments in this study, the lowest average concentration of N-NH3 was 29,2mM and the highest total N-NH3 level was equal to 30,4mM. This figure was higher than Jayanegara et al., (2006) with N-NH3 concentrations of 9,97-13,28 mM in in vitro feeding supplemented with Chromium in organic and inorganic forms. According to Evvyernie et al. (2019), the optimal N-NH3 concentration that supports rumen microbial protein synthesis was 6-21 mM. The high concentration of N-NH3 indicated that some of the feed protein sources were easily degraded, however, concentrations up to 30,15 mM were still safe for the growth of rumen microbes and hosts.

Conclusion:

Conclusions that can be drawn from this research:

Chromium supplementation in goat feed affects feed consumption, feed digestibility, rumen metabolite products, body weight gain and body condition score (BCS).
The best Chromium-yeast supplementation in optimal fattening goat feed at the level of 1,04-1,36 mg/kg feed

DECLARATIONS

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Author's contribution
Wardhana Suryapratama, Munasik, Titin Widiyastuti, Emmy Susanti performed conceptualization, data curation, formal analysis, investigation, methodology, software, validation, writing original draft; Pambudi Yuwono performed conceptualization, methodology, supervision, writing – original draft, writing, review & editing of the manuscript for important academic levels.

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