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Efficiency of Milk and Methane Production of Dairy Goat: A Study of the Correlation Between Nutrient Use and Lactation Performance

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Abstract

This study aimed to identify the efficiency of milk production, nutrient utilization, lactation performance, and methane production of dairy goats, whose diet is supplemented with garlic flour and organic minerals. This study was conducted for five months, in CV. Susu Abadi, Tegal Regency, Central Java at the Animal Science Feed Stuff Laboratory, Faculty of Animal Science, Jenderal Soedirman University. In all, 16 Sapera goats (first lactation), with an average weight of 39.47 ± 3.80 kg, were studied and the feed given was 3.25% DM/kg BW. The research method was in vivo, using a completely randomized design, involving four treatments. The treatments tested were R0 as basal feed (70% forage + 30% concentrate), R1 (basal feed + rumensin 30 mg/kg DM), R2 (basal feed + 250 ppm garlic), and R3 (R2 + organic minerals; 0.3 ppm Se + 1.5 ppm Cr + 40 ppm Zn lysinate). The data obtained were analyzed, using analysis of variance and correlation analysis. The best value of nutrient utilization was seen for (R3) DMI/Milk Yield of 1.02 ± 0.22, (R2) OMI/Milk Yield of: 0.94 ± 0.13. (R2) OMI/Production of Total Solid: 7.23 ± 1.04, (R2) OMI/Production of Lactose: 25.26 ± 3.36, and (R2) OMI/Production of Casein: 29.93 ± 3.96. The best value of lactation performance was for (R3) 1210.26 ± 273.50 ml. The lowest Methane Production value was indicated by (R3) 1.11 ± 0.13. The highest correlation value was seen in the consumption of crude fiber and crude protein of milk fat production ($R2 = 0.28$). The digestibility values of CP and CF showed significant differences ($P < 0.05$), while the digestibility values of DM and OM did not show any significant differences ($P > 0.0.5$). The consumption values of DM, OM, CP, and CF had no significant differences ($P > 0.0.5$) when observed in the experimental treatments. It can be concluded that the supplementation of 250 ppm garlic flour in goat feed lactation milk results in lower methane production than in the case of all other treatments that were tested. Supplementation of garlic flour and organic minerals (Cr, Se, and Zn) increase the efficiency of milk production, nutrient utilization, and lactation performance in dairy goats.

Keywords: Garlic, Minerals, Lactation, Efficiency , Methane.

Introduction

The low productivity of dairy goats at this time is a result of the inefficiency with which their bodies convert absorbed nutrients into milk. This is due to numerous factors, one of which is that the majority of the energy spent will be converted and released as methane gas. The squandered energy in the form of methane gas would not only have a detrimental effect on the environment, but it will also harm farmers and indirectly affect the sustainability of the livestock industry.

The livestock sector contributes to increasing global warming through the production of carbon dioxide and methane (CH_4) gases from metabolic processes in the rumen. The production of methane gas by ruminant animals accounts for 95% of total methane emissions produced by livestock and humans and approximately 18% of total greenhouse gas emissions in the atmosphere [1]. Methane emissions from ruminants reduce the use of available feed energy for production, with a loss of around 3–12% of digestible energy [4]. Thus, efforts to suppress methane gas production have benefits in the short term, namely being able to reduce energy loss in livestock, and in the long term can reduce the rate of global warming [1].

Supplementation of dairy goats is one method for improving milk production performance. Supplementation is carried out using traditional feed ingredients and is made from organic ingredients so that they do not have negative side effects and also do not leave harmful residues in livestock, so that products produced from livestock will remain safe when consumed by humans. The supplementation carried out in this study was the addition of garlic (*Allium sativum*) and organic minerals Cr, Se, and Zn to the feed.

At the end of the pregnancy period (prepartum), there will be a tendency for a negative energy balance to occur. Therefore, special attention is needed during this period. The addition of Cr, Se, and Zn minerals plays an important role in maintaining the performance of the dairy goat production. Utilization of garlic (*Allium sativum*) prepartum , there will be a tendency for a negative energy balance to occur. Therefore, special attention is needed during this period. The addition of Cr, Se, and Zn minerals plays an important role in maintaining the performance of the dairy goat production. Utilization of garlic (Allium sativum), which has a high content of allicin, can increase the productivity of dairy goats [15].

Garlic powder and organic minerals in the form of Cr, Se, and Zn-Lysinate can boost milk synthesis [16]. The allicin component in garlic can inhibit the growth of methanogens so that energy efficiency, energy that would have been lost (wasted into methane) will be utilized again to increase milk synthesis. In the body, chromium acts as a glucose tolerance factor (GTF), which is a component on the cell surface that, together with insulin, can facilitate the entry of glucose into cells. [25] said that the more glucose that is absorbed in the body, the more lactose that is formed, which is one of the major components of milk. The role of selenium is to protect secretory cells from free radicals and to increase the number of secretory cells in the mammary glands; the function of zinc is to inhibit milk production during the first and second lactations.

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Materials and Methods

Ethical Approved

Using animal and scientific procedures in this study has been approved by Animal Ethics Committee in the Faculty of Animal Science, Jenderal Soedirman University, Indonesia.

Livestock, experimental design, livestock treatment and treatment design

The livestock used were female Saanen Peranakan Ettawah crossbreed goats (Sapera) with an average age of 14 months (*primiparous*) totaling 16 heads with an average body weight of 39.47 ± 3.80 kg. The design used a completely randomized design. The treatments consisted of R0 : 70% native grass + 30% concentrate (CP : 12.20%; TDN : 52.18 %), R1 : R0 + 30 mg/BW Rumensin, R2 : R0 + 250 ppm garlic flour, R3: 1.5 ppm organic Cr; 0.3 ppm organic Se; 40 ppm organic Zn, which was repeated as much as four times. Feed is given as much as 3.25% of body weight and drinking water was given ad libitum. Feeding was given twice, namely in the morning and afternoon and the treatment feed was given after 14 preliminary days, namely for 30 days. Garlic flour preparation followed the method of [15] and the manufacture of organic Cr,Se,Zn minerals based on [14].

Table 1. Nutrient composition of the experiment

No	Feedstuff	R0	R1	R2	R3
1	Native grass (%)	70	70	70	70
2	Concentrate (%)	20	20	20	20
3	Dregs Tofu (%)	10	10	10	10
4	Rumensin (mg/kg BW)	0	30	0	0
5	Garlic Flour (ppm)	0	0	250	250
6	Organic Minerals (ppm)				
	Se	-	-	-	0.3
	Cr	-	-	-	1.5
	Zn-lysinat	-	-	-	40

The concentrate ingredients consisted of pollard, soybean meal, coconut meal, corn gluten feed (CGF), soybean groats, kleci (outlayer of soy), salt, mineral mix, and amino acid lysine.

Animal feeding and management

The Sapera goats were raised in individual pens. The feeds were given 3.25% of body weight and the water were given ad libitum. The diet was offered to the animal twice every day at 06.30 AM and 03.30 PM. The refusal feed was collected and weight in the morning before the new feed was given.

Digestion trial, chemical, analysis and milk production measurement

The feed digestion experiment was carried out for 7 days using the total collection method. The feed is given, the refusal of the feed and the feces of each experimental unit were weighed and recorded every day. In the total collection, the feed given and the remaining feed were collected for each experimental unit of 100 grams each, while the feces samples were 250 grams. Samples of feed and the refusal were dried in an oven at 60^{o}C, while the feces were stored at 18^{o}C. Measurement of dry matter, crude protein, crude fiber, crude fat and ash in feed and feces refers to the AOAC (2006). Measurement of feed and feces nitrogen refers to the Kjeldahl method.

Milk production was measured 7 days after the goat gave birth and was measured for 50 days. Milk samples taken in the morning and evening milking as much as 25 ml were stored in the refrigerator to be measured: lactose, casein, fat, BJ and total solids with type lactoscan LW3030 made in Switzerland. Frozen milk samples were thawed before being read on the lactoscan.

Measurement of Nutrient Consumption and Digestibility

The recording of the amount of consumption and the rest of the feed was carried out for 4 weeks and in the last 7 days, samples were taken and the collection of feeding and leftover feed. The administration and the remaining forage were taken as much as 100 g and the administration and the remaining concentrate were taken as much as 10 g from the daily amount and then composited for 7 days of sampling. The sample was sun-dried, followed by baking at 70 °C for 2 days, and then reheated at 105 °C for a day. Dried samples are then ground down for analysis of feed ingredient composition according to AOAC (2006).

Steps for measuring nutrient digestibility: Fecal and feed samples taken were oven-dried at 60 °C for 48 hours, ground, and filtered through a 1 mm sieve and stored in a ziplock plastic bag for analysis. Using the principle of proximate analysis, to determine the value of dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (CF) and ether extract (EE), the analysis was carried out according to standard procedures (AOAC, 1995). Digestibility is calculated using the formula [20]:

1. Apparent digestibility (g/kg) = Nutrient Intake – Nutrient Output / Nutrient Intake.
2. Nutrien intake = feed nutrient levels x amount of dry matter eaten
3. Nutrien Output = faecal nutrient levels x amount of fecal dry matter

Measurement of Lactation Performance

The lactation performance of dairy goats was calculated by adding up the milk production produced by the cattle every day, 6 days after the mother gave birth. To determine the quality of dairy goat milk, it can be done using a previously calibrated lactoscan device. 25 ml of freshly milked milk was taken to measure its nutrient composition with Lactoscan type LW3030 made in Switzerland.

Measurement of Methane Emission Production

Methane Production measurement stages: calculated using the formula:

CH_4 (MJ/d) = 0.223+0.876xDMI (Kg/d) [13].

Methodology

The materials used in this study were 16 Saanen Ettawa dairy goat breeds (heifer/ lactation 1) with an average body weight of 39.47 kg. The research target was dairy goats (Sapera) in Bandasari Village, Dukuhturi District, Tegal Regency, Central Java, Indonesia. The research design used was a Completely Randomized Design (CRD) with four treatments and four repetitions so there were 16 experimental units. The treatments tested are explained as follows:

R0: Basal Feed (70% forage + 30% concentrate)
R1: R0 + Rumensin 30 mg/BW
R2: R0 + Garlic 250 ppm (1.7% allicin)
R3: R2 + Organic minerals (0.3 ppm Se + 1.5 ppm Cr + 40 ppm Zn-lysinate).

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Data Analysis

The data obtained were tabulated into a table and then analyzed using analysis of variance (SPSS software). If the treatment had a significant effect, then the analysis would be continued by using the Honest Significant Difference Test (HSDT).

Results and Discussion

Milk Efficiency, Milk Yield, Production of Total Solid, Lactose, and Casein

Garlic flour supplementation of 250 ppm and organic Cr,Se,Zn affected ($P<0.05$) Milk Efficiency, DMI and OMI:Milk yield, and Production of Total Solid, Lactose, Casein. Also affected ($P<0.05$) Methane and Milk Production but did not affect ($P>0.05$) to the correlation between consumption and digestibility to Milk Production. The average value of all parameters of Sapera goats supplemented with organic Cr,Se,Zn and garlic flour which is presented in Table 1,2,3.

Tabel 1. Variabel of Nutrien Utilization

Parameter	R0	R1	R2	R3	p-value
Milk efficiency: DMI Milk yield	1.57 ± 0.15^{b}	1.22 ± 0.23^{ab}	1.02 ± 0.13^{a}	1.02 ± 0.22^{a}	0.005
OMI:Milk Yield	1.45 ± 0.11^{b}	1.10 ± 0.20^{ab}	0.94 ± 0.13^{a}	0.94 ± 0.24^{a}	0.005
OMI:Production of Total Solid	10.01 ± 0.94^{b}	8.43 ± 1.45^{ab}	7.23 ± 1.04^{a}	7.31 ± 1.14^{a}	0.018
OMI:Production of Lactose	35.79 ± 2.18^{b}	29.88 ± 6.00^{ab}	25.26 ± 3.36^{a}	25.81 ± 6.82^{a}	0.039
OMI:Production of Casein	42.45 ± 2.59^{b}	35.45 ± 7.11^{ab}	29.93 ± 3.96^{a}	31.59 ± 7.48^{a}	0.039

(DMI: dry matter intake, OMI: organic matter intake)

Tabel 2. Methane and Milk Production

Parameter	R0	R1	R2	R3	p-value
Methane Production (Mj/d)	1.38 ± 0.10^{a}	1.18 ± 0.17^{a}	1.11 ± 0.13^{a}	1.27 ± 0.17^{a}	0.131
Milk Production (ml)	841.09 ± 20.98^{a}	902.53 ± 9.89^{a}	1000.43 ± 22.20^{ab}	1210.26 ± 273.50^{b}	0.031

Discussions

DMI:MILK YIELD

The results of this study indicated that the value of changes in dry matter intake (DMI)-milk production was significantly different between each treatment ($P<0.05$). The results of this study also showed that the value of dry matter intake that turns into the best milk production is the R3 treatment, and the lowest is indicated by R0. This is because the treatment that did not receive any supplementation (R0) had a tended to for the value of changes in dry matter intake (milk production) to be much lower, resulting in low milk

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production, as well as the conversion value (R0), which was the highest, meaning the higher the value of the change in dry matter consumption (milk production) would cause a decrease in the efficiency of the feed consumed and the amount of milk produced. Cr-methionine supplementation can increase dry matter consumption and milk production at the start of lactation; this is in line with the research results obtained [3]. When compared to the (R0) value of the control feed without any supplementation, the (R3) value is much higher because (R3) contains supplementation in the form of organic chromium minerals and garlic, although the values were not significantly different from the (R2) treatment.

Chromium mineral supplementation in much 0.8 ppm can increase milk production in primiparous cattle but not in multiparous cattle [3]. This is in line with the research results conducted by the researchers of this study, which showed that there was an increase in milk production of 69.5% in the first lactating cattle (heifer) used. The milk production for R0 was only 841.09 ± 20.98 ml, while the milk production for R3 was 1210.26 ± 273.50 ml. This shows a significant and significantly different increase in milk production in the treatment supplemented with garlic and organic minerals. In addition to organic minerals, garlic also played a significant role in increasing milk production. This is due to an increase in the intake of dry matter consumption which would increase milk production and would also reduce its conversion value. Previous research revealed an increase in dry matter consumption in lactating Murrah Buffalo. Although the treatment was not significantly different, it still showed an increase in dry matter consumption [27]. In Murrah buffalo lactation, increased milk production occurred in buffaloes that were given garlic powder supplementation at the beginning to the end of the study period (1-11 weeks) when compared to the control treatment, treatment with garlic supplementation would be much higher in producing milk [27].

The minerals selenium and zinc are micro minerals, which were given only in small amounts but have great functions and benefits for ruminants. Selenium yeast had a positive effect on increasing the amount of milk production in goats and dairy cows [19]. Milk production in dairy goats supplemented with organic selenium was higher than that of milk production compared to inorganic selenium. Selenium in organic form can increase milk production higher when compared to inorganic selenium. This is due to the fact that organic selenium can boost the expression of the -S2-casein (CSN1S2) gene.

OMI:MILK YIELD

The findings of this study demonstrated that each treatment significantly affected the value of changes in the consumption of organic matter-milk production ($P<0.05$). According to the study's findings, the (R2) treatment has the highest organic matter consumption value, whereas (R0) has the lowest and results in the best milk output. This is possible because the treatment that received no supplementation (R0) tended to have a value of changes in organic matter consumption-milk production that was much lower, resulting in low milk production and the highest conversion value (R0), which means that the higher the value of changes in organic matter consumption-milk production would result in a decrease in the efficiency of the feed consumed and the amount of milk produced. R0 was the lowest (without treatment) and R3 was the greatest, according to the data on the value of dry matter consumption.

The results are consistent with the theory put forth by [7] that since dry matter's organic matter composition made up the majority of it, organic matter (OM) consumption would follow the same pattern as dry matter (DM) consumption. The benefit of consuming organic matter would follow the outcomes of consuming DM [22]. Since DM consumption at (R0) was lower than it is for the other treatments, changes in organic matter-production of goat milk at (R0) would likewise be larger (with the lowest efficiency value) than they were for goats receiving the other treatments. Low levels of DM and OM intake in animals would be the result of low levels of BK consumption.

Even if the data was not statistically different, the results supported the belief of [7] that there is a similar pattern of rising organic matter consumption. The value of organic matter consumption would be lower in feed supplemented with onions than in control feed (feed without treatment) minerals that were white and organic. The addition of organic chromium minerals can boost feed intake without influencing the amounts of milk's constituents, and it doesn't make livestock less sensitive to cold stress [3]. In its physiological form, chromium serves as an Insuline-Like Growth Factor (IGF-I), which can boost the absorption of amino acids and glucose in mammary gland cells, boosting milk production [12]

MILK EFFICIENCY

The results indicated that the variable efficiency of milk production is significantly different ($P>0.05$). The variable efficiency of milk production between treatments (R2) and (R3) tends not to be significantly different, but when compared to treatment (R0), it will have a significant difference. Treatment (R0) has the highest value (meaning it has the lowest milk efficiency value). This is because treatment R0 is a control treatment, while treatments (R2) and (R3) have been supplemented with garlic and organic minerals in the feed. The content of the allicin compound, which is a bioactive sulfur component naturally found in garlic (*Allium sativum*) can increase the value of energy use efficiency in the rumen of ruminants. Garlic contains natural compounds such as allicin, diallylsulfide, and diallyldisulfide, which can be used in ruminant rations and have shown promising results in modifying rumen microbial fermentation patterns, and as a result, the value of acetic acid decreases, propionate and butyrate production increases, and energy efficiency in the rumen increases [27]. Effective garlic supplementation in Murrah buffalo ruminants is 4% DM because garlic supplementation at 2% DM has not increased the ratio of propionic acid, whereas at a dose of 6% DM it will actually be toxic and reduce the amount of propionic acid, the higher the acid content. propionate produced will be more efficient in producing milk [27].

Chromium mineral supplementation in this study is closely related to increased energy efficiency and milk production efficiency. Basically, chromium is responsible for increasing insulin sensitivity so that the absorption of glucose in cells becomes better and less energy is wasted in the form of methane. Organic Cr minerals can be used to improve reproductive parameters, increase growth, increase feed conversion efficiency, increase immunity, and reduce mortality [28]. Cr methionine mineral supplementation can linearly increase the efficiency of prepartum feed [18]. Supplementation of Cr, Se, and Zn proteinate minerals by giving 1.5; 0.3; or 40 ppm can improve feed efficiency [14]. Organic Zn supplementation can reduce the number of somatic cells that cause sub-clinical mastitis in dairy cows and can increase daily milk yield [23]. It can be concluded that the addition of organic minerals and garlic together can replace the role of rumensin as a commercial mineral whose price tends to be more expensive. The addition of organic minerals and garlic can also increase milk production efficiency when compared to feed that is not supplemented with garlic and organic minerals (Cr, Se, and Zn).

TOTAL PRODUCTION OF MILK SOLID, LACTOSE, AND CASEIN

Milk protein, lactose, total solids, and solid non-fat were all significantly impacted by the garlic powder ration in the first month of lactation. According to the study's findings [8] an increase in rumen microbial protein production would cause milk protein levels to rise along with the administration of garlic flour, which will also raise lactose, total solids, fat, and solid non-fat levels (casein).

The results showed that changes in the value of consumption of organic matter-lactose production in treatments (R2) and (R3) would be lower than the control feed, meaning that it had a better level of efficiency in lactose production. This was due to the supplementation in the form of garlic powder and organic minerals. Following with the research results obtained by [11] there was an increase in milk lactose levels in the treatment given 0.1 mg of organic selenium, while the control treatment without selenium was 4.28 after being given selenium at 4.45. This shows that the mineral selenium plays an important role in increasing milk lactose production.

The significant increase in milk casein production between treatment (R3) and treatment partners (R0), (R1), and (R2) was caused by an increase in the amount of lactose production in milk, which is the largest component in milk. The higher the lactose content of milk, the higher the milk casein level, the casein content greatly affects the process of milk synthesis because the protein in feed is used by the body in the process of forming milk [2]. The thing that affected the higher (R3) treatment compared to (R2), even though both were given garlic powder supplementation, was the presence of organic minerals such as selenium, chromium, and zinc in the (R3) treatment. The function of organic minerals is to increase udder secretory cells and increase insulin absorption. The addition of Cr in the feed will increase the insulin receptors of the mammary gland secretory cells, while Se is to maintain the secretory cells of the udder glands [16]. Increased insulin receptors from secretory gland cells will bind to a greater concentration of glucose; the higher the glucose absorbed, the greater the milk production.

R2 treatment has an average value of change in consumption of organic matter-solid nonfat production of 7.23 ± 1.04, 2.78 different from R1 treatment, which has a higher conversion value (lower lactose production efficiency value). This is because feed treated with R2 gets garlic powder (*Allium sativum*) supplementation, which can increase the production of solid nonfat milk. Garlic flour (*Allium sativum*) contains allicin, which has antimethanogenic properties and can affect bacterial growth, thereby affecting nutrient absorption and increasing feed digestibility [6]. Absorption of these nutrients by redirecting energy used for methane gas formation into energy for milk synthesis, resulting in an increase in milk production.

Garlic powder (*Allium sativum*) administration increased the formation of solid non-fat by 0.38 mg/dl, according to the findings of other researchers [17]. This is because the garlic ingredient allicin is known to boost propionic acid production while decreasing methane gas generation. Fermentation of carbohydrates produces propionic acid, which is then converted to glucose in the liver. One of the precursors in the synthesis of lactose in milk is glucose.

METHANE PRODUCTION

The results showed that the methane production variable was significantly different ($P<0.05$) between each treatment. Methane production variables tend to be significantly different between the averages of each treatment. The R0 treatment had the highest methane gas production value when compared to the three treatments. The high production of methane gas in the control diet was due to the high levels of acetic acid produced in the rumen. The higher the production of acetate in the rumen, the higher the production of methane gas. This happens because the stoichiometry of acetate formation will always be followed by the formation of H_2 ions which are precursors in the formation of methane gas. Unlike the case with treatments R1, R2, and R3 because each of these treatments function as a methane inhibitor. The effect of giving garlic powder on the fermentation pattern that occurs in the rumen is to divert the use of H_2 ions for the formation of methane gas toward the formation of propionate [15] Methanogens are capable of converting CO_2 and H_2 into methane either via the hydrogenotrophic pathway or, through the methylotrophic pathway, thereby producing methane gas using methylamine and methanol as substrates. The process of methanogenesis is important to consider in ruminants because the hydrogen produced during carbohydrate fermentation, if not removed, can inhibit the metabolic processes of the rumen microbiome [9]. Reduced rumen *Archeae bacteria as a result of the presence of allicin* which inhibits the work of the Archea HMG CoA (*Hydroxymethylglutaryl Coenzyme Acetil*) reductase enzyme so that *Archeae* membranes are not formed and there is a transfer of H_2 used for the formation of propionate resulting in an increase in energy efficiency.

The results showed that the R_2 treatment had the lowest methane, namely 1.11 ± 0.13 Mj/d. This shows that garlic can suppress the activity of methanogens in producing methane gas. When compared with research [21], basal feed (elephant grass and legumes) with a TDN content of 57.95% given to male kacang goats without any supplementation produces relatively high methane gas, which is equal to 1526.3-2096.8 litters per kg or equivalent to 1,530-2,090 Mj/d. The results of other researchers showed that the production of methane gas produced in sheep fed basal feed in the form of forages (corn, soybeans, hay) and concentrates was 1.11-1.14 Mj/d [10]. So it can be concluded that the addition of garlic and organic minerals can reduce methane gas production.

Rumensin is a feed additive that can be used to reduce methane production because it contains antimicrobial compounds that can increase the production efficiency of ruminants [24]. It can be concluded that the absence of methane inhibitors in the R0 treatment caused methane gas production to be higher than the other three treatments. The higher the methane gas produced, the lower the utilization of feed energy that has been metabolized so the energy is not utilized properly.

Conclusion

Based on the results of the study, it can be concluded that the supplementation of 250 ppm of garlic powder in the feed of lactating dairy goats resulted in lower methane production than all the treatments tested. Supplementation of garlic powder and organic minerals can increase the efficiency of milk production, nutrient use, and lactation performance.

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Conflict of interest

The authors have declared no conflict of interest

Author's contribution

All authors contributed to conducting research and writing this manuscript

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