

ARTICLE INFORMATION	Fill in information in each box below
Article Type	Research article
Article Title (within 20 words without abbreviations)	Identification of the optimal monosodium glutamate–condensed molasses soluble inclusion level replacing molasses in growing-finishing pigs
Running Title (within 10 words)	Replacing molasses with MSG-CMS in growing-finishing pig
Author	Jinmo Yang ^{1, #} , Sooyoung Park ^{2, #} , Jihwan Lee ^{3, #} , Minho Song ^{4, #} , Seyoen Chang ¹ , Dongcheol Song ¹ , Kyeongho Jeon ¹ , Hyuck Kim ¹ , Jihong Jung ² , Won Yun ⁵ , Hyeunbum Kim ^{6, *} , Jinho Cho ^{1, *}
Affiliation	¹ Department of Animal Science, Chungbuk National University, Cheongju 28644, Republic of Korea ² NongHyup Feed Inc, Seoul 05398, Republic of Korea ³ Swine Science Division, National Institute of Animal Science, Rural Development Administration, Cheonan 31000, Republic of Korea ⁴ Division of Animal and Dairy Science, Chungnam National University, Daejeon 34134, Republic of Korea ⁵ Central Research Institute, Woosung Feed Co., Ltd, Daejeon 34379, Republic of Korea ⁶ Department of Animal Biotechnology, Dankook University, Cheonan 31116, Republic of Korea
ORCID (for more information, please visit https://orcid.org)	Jinmo Yang / mike000315@gmail.com (https://orcid.org/0009-0007-4272-3441) Sooyoung Park / parksy0228@naver.com (https://orcid.org/0009-0009-6777-8646) Jihwan Lee / junenet123@naver.com (https://orcid.org/0000-0001-8161-4853) Minho Song / mhsong@cnu.ac.kr (https://orcid.org/0000-0002-4515-5212) Seyoen Chang / angella2425@naver.com (https://orcid.org/0000-0002-5238-2982) Dongcheol Song / paul741@daum.net (https://orcid.org/0000-0002-5704-603X) Kyeongho Jeon / jeonkh1222@gmail.com (https://orcid.org/0000-0003-2321-3319) Hyuck Kim / harrck85@naver.com (https://orcid.org/0000-0002-5280-0734) Jihong Jung / jjihong0309@hanmail.net (https://orcid.org/0009-0006-1646-3124) Won Yun / wyoun@woosung.kr (https://orcid.org/0000-0002-1835-2640) Hyeunbum Kim / hbkim@dankook.ac.kr (https://orcid.org/0000-0003-1366-6090) Jinho Cho / jinhcho@cbnu.ac.kr (http://orcid.org/0000-0001-7151-0778)
	No potential conflict of interest relevant to this article was reported.
Funding sources State funding sources (grants, funding sources, equipment, and supplies). Include name and number of grant if available.	This work was supported by Nonghyup Feed inc., Republic of Korea
Acknowledgements	No applicable.
Availability of data and material	All data generated or analyzed during this study are included in this published article.
Authors' contributions Please specify the authors' role using this form	Conceptualization: Cho JH, Jung JH, Park SY Data curation: Yang JM, Jeon KH, Kim H Formal analysis: Park SY, Song DC, Chang SY Methodology: Jung JH, Kim H, Yun W

	Software: Lee JH, Chang SY Validation: Song MH, Song DC, Jeon KH Investigation: Park SY, Yang JM, Kim HB Writing - original draft: Cho JH, Yang JM, Lee JH, Park SY Writing - review & editing: Cho JH, Kim HB, Song MH, Yang JM, Yun W, Lee JH, Jung JH, Park SY, Chang SY, Song DC, Jeon KH, Kim H
Ethics approval and consent to participate	The experimental protocol was approved (CBNUA-24-0013-02) by the Institutional Animal Care and Use Committee of Chungbuk National University, Cheongju, Korea.

1 **CORRESPONDING AUTHOR CONTACT INFORMATION**

For the corresponding author (responsible for correspondence, proofreading, and reprints)	Fill in information in each box below
First name, middle initial, last name	Jinho Cho ¹ Hyeunbum Kim ⁵
Email address – this is where your proofs will be sent	¹ jinhcho@chungbuk.ac.kr ⁵ hbkim@dankook.ac.kr
Secondary Email address	
Address	¹ Department of animal science, Chungbuk National University, Cheongju 28644, Korea ⁵ Department of Animal Biotechnology, Dankook University, Cheonan 31116, Korea
Cell phone number	¹ +82-10-8014-8580 (Jinho Cho)
Office phone number	¹ +82-43-261-2544 (Jinho Cho) ⁵ +82-41-550-3653 (Hyeunbum Kim)
Fax number	+82-43-273-2240 (Jinho Cho)

2

3 **Abstract**

4 This study aimed to evaluate the effects of replacing molasses with monosodium glutamate (MSG)-
5 condensed molasses solubles (CMS) in growing-finishing pig diets and determining the optimal
6 replacement ratio. Experiment 1, a total of 100 crossbred growing-finishing pigs [(Landrace × Yorkshire)
7 × Duroc] (9 weeks of age; initial body weight 23.17 ± 3.51 kg) were randomly assigned to five dietary
8 treatments for 14 weeks. Pigs were randomly assigned to five dietary treatments with 5 replicates of 10 pigs
9 per pen. The treatments consisted of: (1) PC (basal diet with 2% molasses), (2) NC (basal diet), (3) T1
10 (basal diet with 1.5% molasses + 0.5% MSG-CMS), (4) T2 (basal diet with 1% molasses + 1% MSG-CMS),
11 and (5) T3 (basal diet with 2% MSG-CMS). Growth performance, nutrient digestibility, blood profiles,
12 fecal microbiota, and economic efficiency were assessed. Average daily gain in the T1 was higher ($p < 0.05$)
13 than that in the T3. The average daily feed intake in the T3 was lower ($p < 0.05$) than that in the other
14 groups. In contrast, T1 and T2 had higher ($p < 0.05$) average daily feed intake than other groups.
15 Economically, the T1 showed higher total weight gain and lower ($p < 0.05$) feed cost per kg gain than the
16 NC and T3 during the growing phase. Experiment 2, a total of 5 crossbred growing-finishing pigs (11 weeks
17 of age; initial body weight 36.84 ± 0.51 kg) were used in a 5-week metabolism trial based on a 5×5 Latin
18 square design to investigate the effects of MSG-CMS on nutrient digestibility and nitrogen retention. The
19 T1 had higher ($p < 0.05$) gross energy digestibility than the T3. Fecal nitrogen retention was lower ($p <$
20 0.05) in the T1 and NC than in the T2, while the T2 had higher ($p < 0.05$) total nitrogen retention than the
21 NC. In conclusion, Molasses can be replaced with MSG-CMS without negative effects, with 25%
22 replacement being the most effective for improving growth performance, nutrient digestibility, and
23 economic efficiency in growing-finishing pigs.

24

25 **Keywords (3 to 6):** feed additive, MSG-CMS, growth performance, nutrient digestibility, economic
26 efficiency, swine

27

INTRODUCTION

Molasses, a by-product of sugar production from crops such as sugarcane, is widely used as an energy source and primarily as a palatability enhancer in livestock feed due to its high contents of sucrose, glucose, fructose, and minerals [1]. However, a recent decrease in the production of molasses combined with its increasing global demand and disruptions in transportation through the Panama and Suez Canals have led to a continuous rise in raw material costs, thereby exacerbating the economic burden associated with its use as a feed additive [2].

In response to rising costs and the unstable global supply of molasses, increasing attention has been given to monosodium glutamate–condensed molasses soluble (MSG-CMS), a fermentation derived by-product that is generally more affordable due to its stable local availability, lower processing requirements, and minimal competition with other industrial uses [3]. MSG-CMS is a secondary by-product obtained during monosodium glutamate (MSG) production via microbial fermentation, in which molasses serves as the primary carbon source [4]. During fermentation, microorganisms consume sugars from molasses, producing glutamic acid and other amino acids concentrated in CMS [5]. In addition to these economic and availability benefits, CMS contains glutamic acid and other amino acids derived from fermentation, which support palatability and nutritional value in swine diets [2, 6]. Furthermore, it provides approximately 32% crude protein (CP) and essential minerals (including potassium, chloride, and sulfur), further enhancing its value as a feed ingredient for livestock [7]. Given these nutritional characteristics, several studies have recently evaluated the efficacy of MSG-CMS in animal diets [5,8], including its potential role as a palatability enhancer. Previous studies have shown that dietary inclusion of MSG-CMS can improve feed intake (FI) and average daily gain (ADG) in growing-finishing pigs [2], and that replacing 2% molasses with CMS does not compromise growth performance while increasing backfat thickness [7]. These findings suggest that CMS may serve as an effective palatability enhancer like molasses.

However, previous studies have primarily focused on growth performance, leaving critical factors such as nutrient utilization, blood profiles, fecal microbial, and cost-effectiveness relatively unexplored, although these factors are all key aspects that must be addressed to comprehensively evaluate MSG-CMS in pig diets. Therefore, this study aimed to determine the optimal substitution rate of molasses with MSG-CMS in growing-finishing pig feed by evaluating its effects on growth performance, nutrient digestibility, blood profiles, fecal microbiota, and economic efficiency.

MATERIALS AND METHODS

Ethics approval and consent to participate

The protocol for this study received approval after review by the Institutional Animal Care and Use Committee at Chungbuk National University in Cheongju, Korea (approval no. CBNUA-24-0013-02).

Preparation of molasses and MSG-CMS

Molasses was sugarcane-derived syrup provided by NongHyup Feed (Suwon, Korea) and used as an energy and palatability source. MSG-CMS was a condensed liquid co-product from the monosodium glutamate production process, also provided by NongHyup Feed. Both ingredients were top-dressed and thoroughly mixed with the basal diet before feeding.

Experiment 1

Experimental design, animals, and housing

A total of 100 crossbred pigs ([Landrace × Yorkshire] × Duroc) with an initial body weight (BW) of 23.17 ± 3.51 kg at 9 weeks of age were used for 14 weeks. The pigs were randomly assigned to five dietary treatments with four replicates per treatment and five pigs per replicate. The experimental treatments included: 1) PC (basal diet with 2% molasses); 2) NC (basal diet); 3) T1 (basal diet with 1.5% molasses and 0.5% MSG-CMS); 4) T2 (basal diet with 1% molasses and 1% MSG-CMS); and 5) T3 (basal diet with 2% MSG-CMS).

The experimental period was divided into two phases: a growing phase (0–6 weeks) and a finishing phase (6–14 weeks) according to the nutrient requirements suggested by NRC [9]. MSG-CMS was incorporated into the diets based on the molasses replacement ratio designated for each treatment group (Table 1). Throughout the entire experimental period, pigs had ad libitum access to feed and water.

Sampling and Analysis

Growth performance and Backfat thickness

BW was measured at the beginning of the experiment and subsequently at 3, 6, 10, and 14 weeks (end of the trial). FI was calculated by subtracting the remaining feed from the amount provided at each BW

86 measurement interval. ADG was determined by dividing the BW difference during each period by the
87 number of days in that period. Feed efficiency was calculated as the ratio of ADG to average daily feed
88 intake (ADFI).

89

90 **Nutrient digestibility**

91 To evaluate nutrient digestibility, 0.2% chromium oxide (Cr_2O_3) was added to the experimental diets as
92 an indigestible marker at 6, 10, and 14 weeks. Fresh fecal samples were collected using the rectal massage
93 method. Diet samples containing chromium oxide were also collected and stored at -20°C alongside fecal
94 samples until further analysis. Before analysis, fecal samples were dried in an oven at 60°C for 72h and
95 subsequently ground using a Wiley mill. The general nutrient composition and chromium concentrations
96 of diets and feces were analyzed according to AOAC [9] procedures. Gross energy content was determined
97 using an adiabatic bomb calorimeter (Model 6400, Parr Instrument, Moline, IL, USA). Nutrient digestibility
98 was calculated using the following equation:

$$99 \text{ Digestibility (\%)} = \{1 - (\text{Cr}_2\text{O}_3 \text{ concentration in diet, \%} \times \text{nutrient concentration in feces, \%}) / (\text{Cr}_2\text{O}_3 \\ 100 \text{ concentration in feces, \%} \times \text{nutrient concentration in diet, \%})\} \times 100$$

101

102 **Blood profiles**

103 At 6, 10, and 14 weeks, blood samples were collected from the jugular vein of four pigs per treatment
104 using 5 mL syringes. Blood samples (2 mL) were collected into K_3EDTA vacuum tubes, and 3 mL samples
105 were collected into serum separator tubes. Serum samples were centrifuged at 3,000 rpm for 15 min at 4°C .
106 White blood cells (WBC), red blood cells (RBC), lymphocytes, neutrophils, eosinophils, and monocytes
107 were analyzed using an automatic hematology analyzer (ADVIA 120, Bayer, NY, USA). Total protein (TP)
108 was analyzed using the colorimetric method, and blood urea nitrogen (BUN) was analyzed using the urease-
109 glutamate dehydrogenase (GLDH) method. After analysis, TP and BUN values were measured using an
110 automatic chemistry analyzer (Cobas C720, Hoffmann-La Roche, Switzerland).

111

112 **Fecal microbial**

113 Fecal samples were collected from one pig per pen in each treatment at 6, 10, and 14 weeks using the
114 rectal massage method. After collection, samples were immediately transported to the laboratory, suspended

115 in sterile saline solution, and homogenized. The samples were serially diluted from 10^{-3} to 10^{-7} and used
116 for microbial enumeration. Harmful bacteria, *Escherichia coli*, were cultured using MacConkey agar, while
117 beneficial bacteria, *Lactobacillus*, were cultured using Difco MRS agar. Both types of agar media used for
118 the analyses were purchased from KisanBio (Seoul, Korea). The diluted samples were spread onto each
119 agar medium and incubated at 37°C for 24 h for *E. coli* and 48 h for *Lactobacillus*. Microbial counts were
120 determined and subsequently converted to logarithmic values (log CFU/g) for statistical analysis.

121

122 **Economic efficiency**

123 The economic efficiency of replacing molasses with MSG-CMS in growing-finishing pig diets was
124 performed based on feed costs without considering other associated expenses during the experimental
125 period. Feed cost per kilogram of weight gain was calculated using ingredient costs, total weight gain
126 (TWG), and total feed intake (TFI).

127

128 **Experiment 2**

129 **Experimental design, animals, and housing**

130 A total of five crossbred pigs ([Landrace × Yorkshire] × Duroc) with an initial BW of 36.84 ± 0.51 kg at
131 11 weeks of age were used for 5 weeks in a 5×5 Latin square design experiment. The treatments were
132 identical to those described in Experiment 1. Pigs were individually and randomly housed in metabolism
133 cages (1.2 m × 0.7 m).

134 Experimental diets were formulated and provided as described in Experiment 1. Daily feed allowance
135 was adjusted to 2.7 times the maintenance energy requirement for growing pigs ($2.7 \times 110 \text{ kcal} \times \text{BW}$
136 $\text{kg}^{0.75}$). The daily feeding allowance was divided into two equal portions and fed twice daily at 08:00 and
137 17:00 h. Water was available *ad libitum*.

138

139 **Sampling and Analysis**

140 Apparent total tract digestibility (ATTD) was determined by the total collection method. After an
141 adaptation period of 5 days, pigs were fed experimental diets containing 0.4% chromium oxide (Cr_2O_3) as
142 an indigestible marker. Total feces and urine were collected from the appearance of the marker for the
143 following 3 days. Urine was collected daily into a container with 50 mL of 6 mol/L HCl placed under each

144 metabolism cage to fix nitrogen. Collected feces and urine were weighed and stored at -20°C until analysis.
145 Before analysis, fecal samples were dried in an oven at 60°C for 72h and subsequently ground using a
146 Wiley mill. The chemical composition of the diets and feces was analyzed following AOAC (2007)
147 methods, and gross energy was determined using an adiabatic bomb calorimeter (Model 6400, Parr
148 Instrument, Moline, IL, USA).

149 The ATTD of nutrients and nitrogen retention were calculated using the following equations:

150 Nutrient digestibility (%) = [(Dry matter intake × Nutrient concentration in diet) – (Fecal output × Nutrient
151 concentration in feces)] / (Dry matter intake × Nutrient concentration in diet) × 100

152 Nitrogen retention (%) = [(Nitrogen intake – Nitrogen excreted in feces – Nitrogen excreted in urine) /
153 Nitrogen intake] × 100.

154

155 **Statistical analysis**

156 All data in this study were analyzed utilizing JMP (JMP® Pro version 16.0.0, SAS Institute Inc., Cary,
157 NC, USA). A one-way analysis of variance (ANOVA) was conducted to evaluate differences among
158 treatment groups, and the significance of treatment means was determined using Tukey's multiple range
159 test to assess differences among treatment groups, with significance set at $p < 0.05$. A tendency was
160 considered when $0.05 \leq p < 0.10$. Data are presented as means with their corresponding standard errors.

RESULTS

Experiment 1

Growth performance

The effects of replacing molasses with different ratios of MSG-CMS in growing-finishing pig diets on growth performance are presented in Table 2. During the 0–6 weeks, the T1 showed significantly higher ($p < 0.05$) ADG and G:F than the T3. Additionally, the T3 exhibited significantly less ($p < 0.05$) ADFI than the PC. During 10–14 weeks and 6–14 weeks, the T1 showed significantly higher ($p < 0.05$) ADFI than the NC. Throughout the entire experimental period, the T1 and the T2 showed significantly higher ($p < 0.05$) ADFI than the NC, but no significant differences were observed when compared with the PC.

Nutrient digestibility

The effects of replacing molasses with different ratios of MSG-CMS in growing-finishing pig diets on nutrient digestibility are presented in Table 3. There were no significant differences in DM, CP, and GE digestibility among treatments during the experimental periods.

Blood profiles

The effects of replacing molasses with different ratios of MSG-CMS in growing-finishing pig diets on blood profiles are presented in Table 4. There were no significant differences in blood profiles (WBC, RBC, neutrophils, lymphocytes, eosinophils, monocytes, total protein, and BUN) among treatments during the experimental periods.

Fecal microbial

The effects of replacing molasses with different ratios of MSG-CMS in growing-finishing pig diets on fecal microbial counts are presented in Table 5. There were no significant differences in fecal *E. coli* and *Lactobacillus* counts that were observed among treatments during the experimental periods.

Economic efficiency

The effects of replacing molasses with different ratios of MSG-CMS in growing-finishing pig diets on

189 economic efficiency are presented in Table 6. During weeks 0–6, the T1 showed significantly higher ($p <$
190 0.05) TWG than the NC and the T3. TFI was significantly lower ($p < 0.05$) in the T3 than the PC. The T1
191 exhibited significantly lower ($p < 0.05$) feed cost per kg gain than both the PC and the T3. During the weeks
192 6–14, the T1 and the PC showed significantly higher ($p < 0.05$) TFI than the NC. Throughout the entire
193 experimental period, the T1 and T2 showed significantly higher ($p < 0.05$) TFI than the NC.

194

195 **Experiment 2**

196 **Nutrient Digestibility and Nitrogen retention**

197 The effects of replacing molasses with different ratios of MSG-CMS in growing-finishing pig diets on
198 nutrient digestibility are presented in Table 7. The T1 tended to have lower CP digestibility than the T2 (p
199 = 0.069). While GE digestibility was significantly higher ($p < 0.05$) in the T1 than the T3.

200 The effects of replacing molasses with different ratios of MSG-CMS in growing-finishing pig diets on
201 nitrogen retention are shown in Table 8. Fecal nitrogen retention was significantly lower ($p < 0.05$) in the
202 T1 and NC than in the T2. Total nitrogen retention was significantly higher ($p < 0.05$) in the T2 than in the
203 NC. Nitrogen retention relative to nitrogen intake tended to be higher in the T1 and T3 than in the T2 ($p =$
204 0.079).

205

DISCUSSION

Experiment 1

In comparison to other conventional CMS, MSG-CMS contains relatively lower levels of crude protein, essential amino acids, and minerals [2,6,11]. Nevertheless, its high digestibility and appropriate moisture content enhance its manageability and applicability in feed formulation, highlighting its potential as a valuable ingredient in animal nutrition [12]. However, potential limitations associated with its excessive inclusion, particularly its impact on feed palatability and intake, must also be considered.

Excessive use of flavor additives, such as MSG-CMS, disrupts the overall flavor profile of feed, reduce its palatability and ultimately decrease feed intake [13–15]. In the present study, the treatment in which molasses was completely replaced with MSG-CMS significantly reduced ADFI, ADG, and G:F during 0–6 weeks. The observed decrease was due to reduced feed palatability caused by excessive inclusion of MSG-CMS [6,15]. However, no significant differences were observed during 6–14 weeks. This result suggests that the negative effects of MSG-CMS were reduced over time as pigs adapted to the flavor [17]. In contrast, partial replacement of molasses with 0.5% MSG-CMS showed no adverse effects on growth performance, indicating its potential as an appropriate inclusion level. This is because amino acids and nitrogenous compounds in CMS, which originated from microbial fermentation, improved protein synthesis and maintained nutrient balance [6]. Overall, these findings are consistent with previous research indicating that determining an appropriate inclusion level is critical for the practical application of MSG-CMS as a functional feed ingredient [18-20].

In this study, there were no significant differences in the digestibility of DM (85–88%), CP (67–72%), and GE (77–82%) among treatments, which is attributed to the low inclusion level of MSG-CMS [6]. These results suggest that MSG-CMS, when included at an appropriate level, does not impair nutrient digestibility and can be safely used as a feed ingredient in pig diets. This is consistent with a previous study showing that appropriate inclusion of molasses by-products does not impair nutrient digestibility in pigs [21,22]. Similarly, Stemme et al. [3] also reported similar digestibility values for organic matter (72.3%) and crude protein (71.8%) when CMS was included at 16% in pig diets. However, when CMS was included at levels over 43%, CP digestibility decreased by more than 10% [3].

BUN and total protein levels were evaluated as indicators of protein utilization and overall metabolic status, as they can indirectly reflect nitrogen retention and liver protein synthesis [23,24]. In this study,

235 blood profiles such as WBC, RBC, total protein, and BUN showed no significant differences among
236 treatments. These results indicate that MSG-CMS did not negatively affect metabolic health, which is
237 consistent with previous studies reporting that MSG had no adverse effects on blood profiles related to
238 metabolism [25-27]. Therefore, MSG-CMS can be considered metabolically safe and nutritionally
239 acceptable when used at appropriate levels [28,29].

240 Fecal microbiota are dynamic biomarkers affected by large intestinal fermentation, environmental factors,
241 and dietary components such as soluble carbohydrates and organic acid compounds [30,31]. They are
242 closely associated with nutrient digestibility, immune function, and animal productivity [32,33].
243 *Lactobacillus* is a beneficial microbe that can enhance gut health and nutrient absorption, whereas excessive
244 *E. coli* intestinal function, making their balance a key indicator of intestinal microbial status [34]. In this
245 study, no significant differences in fecal microbial composition were observed among treatments. This
246 result is likely due to attributed to the relatively low substitution level of MSG-CMS [35,36]. Therefore,
247 while this finding suggests that MSG-CMS at low inclusion levels does not negatively impact the microbial
248 balance in feces, further studies are needed to evaluate its effects at higher substitution levels.

249 MSG-CMS, a secondary by-product of MSG production, is more affordable and requires less processing
250 than other fermentation-derived additives such as yeast extract or *Lactobacillus* products [37]. This
251 economic advantage enhances its practicality as a feed additive in commercial pig diets [38]. In the present
252 study, pigs fed MSG-CMS diets showed a tendency toward improved feed cost efficiency without a
253 negative effect on FI, aligning with its economic potential. This result indicates its potential as a cost-
254 effective additive for pig diets [39]. Similarly, Park et al. [40] reported that partial replacement of high-cost
255 protein sources such as spray dried porcine plasma with hydrolyzed proteins significantly reduced feed
256 costs without negatively affecting growth performance in pigs, suggesting that low-cost alternatives like
257 MSG-CMS may offer comparable economic benefits. Shahini et al [41] have emphasized that feed cost
258 reduction is a key strategy for improving farm profitability, especially under rising input prices. This
259 perspective supports the economic applicability of MSG-CMS as a low-cost additive in swine production.

260

261 **Experiment 2**

262 Metabolic trials offer controlled conditions with limited animal movement, which contribute to reduced
263 variability and enable accurate measurement of nutrient digestibility and metabolism [42,43]. Under
264 controlled conditions, reduced GE digestibility was only observed when MSG-CMS completely replaced

265 molasses. MSG-CMS contains significantly lower levels of monosaccharides such as sucrose and glucose
266 than molasses [44]. This is because it is a by-product of MSG production that undergoes different
267 processing steps known to reduce the contents of monosaccharides [4]. Monosaccharides are rapidly
268 absorbed in the small intestine and directly utilized as an immediate energy source [45,46]. Therefore, a
269 reduction in monosaccharide intake, as observed in complete MSG-CMS replacement, reduces the supply
270 of absorbable energy in the intestinal tract [47]. Consequently, it impairs the development of the intestinal
271 tract and reduces the synthesis or activity of digestive enzymes over time, ultimately decreasing GE
272 digestibility [48]. Accordingly, maintaining an appropriate inclusion level of MSG-CMS is considered
273 important to support optimal digestive function.

274 MSG-CMS is not regarded as a primary protein source but contains amino acids and nitrogenous
275 compounds derived from microbial fermentation, which can contribute to nitrogen utilization in pig diets
276 [34]. However, previous studies have reported that CMS supplementation reduces reduce nitrogen
277 digestibility and increase nitrogen excretion, depending on the inclusion level and diet composition [49].
278 In the present study, nitrogen excretion tended to decrease in the T1 group, which contained a lower level
279 of MSG-CMS in combination with molasses, whereas this effect was not observed in T2 and T3, where
280 MSG-CMS was included at higher levels. This suggests that moderate supplementation of MSG-CMS,
281 when combined with fermentable carbohydrates such as molasses, may be more effective in improving
282 nitrogen metabolism. Molasses provides fermentable carbohydrates, including non-starch polysaccharides,
283 that serve as energy sources for intestinal microbes and epithelial cells [50,51], and enhance microbial
284 fermentation in the large intestine [34,52]. These microbial activities can support microbial protein
285 synthesis and nitrogen retention, thereby contributing to improved nitrogen utilization [53]. In contrast,
286 high inclusion levels of MSG-CMS have adverse effects on nitrogen balance due to limited digestibility
287 or metabolic burden [54]. Taken together, these findings indicate that a balanced combination of
288 fermentable carbohydrates and nitrogenous compounds is critical for optimizing nitrogen utilization.
289 Further studies are needed to determine the optimal inclusion levels of MSG-CMS and to clarify the
290 underlying mechanisms involved.

Conclusion

291

292 This study supports the feasibility of partially replacing molasses with MSG-CMS in growing-finishing
293 pig diets. Specifically, a 25% replacement of molasses with MSG-CMS improved ADG, G:F, GE
294 digestibility, and economic efficiency without negative impacts on blood profiles or fecal microbiota.
295 Future studies should explore higher inclusion rates or extended feeding durations to clarify physiological
296 and microbial responses to MSG-CMS.

297

ACCEPTED

REFERENCES

- 299 1. Choi IH. Effects of dietary microbial-fermented molasses on egg production and egg quality in laying
300 hens. *J Environ Sci Int.* 2019;28(1):159–62. <https://doi.org/10.5322/JESI.2019.28.1.159>
- 301 2. Kim KH, Song IH, Chun JL, Jeon JH, Seo K, Nam KT. Effects of dietary supplementation of condensed
302 molasses soluble (CMS) on growth performance and meat quality in growing-finishing
303 pigs. *J Korea Acad Ind Coop Soc.* 2020;21(11):427–34. [https://doi.org/10.5762/KAIS.2020.21.1](https://doi.org/10.5762/KAIS.2020.21.1.427)
304 1.427
- 305 3. Stemme K, Gerdes B, Harms A, Kamphues J. Beet-vinasse (condensed molasses solubles) as an
306 ingredient in diets for cattle and pigs: nutritive value and limitations. *J Anim Physiol Anim Nutr.*
307 2005;89(3–6):179–83. <https://doi.org/10.1111/j.1439-0396.2005.00554.x>
- 308 4. Damron BL, Hall MF, Harms RH. Condensed molasses solubles in poultry feeds. *Poult Sci.*
309 1980;59(3):673–5. <https://doi.org/10.3382/ps.0590673>
- 310 5. Ma J, Ma C, Fan X, Shah AM, Mao J. Use of condensed molasses fermentation solubles as an alternative
311 source of concentrates in dairy cows. *Anim Biosci.* 2020;34(2):205. <https://doi.org/10.3382/ps.0590673>
- 312 6. Figueroa J, Frías D, Solà-Oriol D, Tadich T, Franco-Rosselló R, Nuñez V, Dwyer DM. Palatability in
313 pigs, the pleasure of consumption. *J Anim Sci.* 2019;97(5):2165–74. <https://doi.org/10.1093/jas/skz085>
- 314 7. Munezero O, Kim IH. Effect of condensed molasses fermentation solubles (CMS) to replace molasses
315 on the growth performance, nutrient digestibility, and backfat thickness in growing pigs. *Korean J Agric*
316 *Sci.* 2022;49(2):185–92. <https://doi.org/10.7744/kjoas.20220015>
- 317 8. Chien YH, Chen CC. Substitution of defatted soybean meal with condensed molasses fermentation
318 soluble in diets for fingerling milkfish (*Chanos chanos* Forsskal). *J Fish Soc Taiwan.* 2007;34(1):11–
319 20.
- 320 9. National Research Council (NRC). Nutrient requirements of swine. 11th ed. Washington (DC): National
321 Academy Press; 2012.
- 322 10. Association of Official Analytical Chemists (AOAC). Official methods of analysis. 18th ed. Arlington
323 (VA): AOAC; 2007.
- 324 11. Palmonari A, Cavallini D, Sniffen CJ, Fernandes L, Holder P, Fagioli L, Mammi L. Characterization of
325 molasses chemical composition. *J Dairy Sci.* 2020;103(7):6244–9. [https://doi.org/10.3168/jds.2019-](https://doi.org/10.3168/jds.2019-17644)
326 17644

- 327 12. Shurson GC, Hung YT, Jang JC, Urriola PE. Measures matter—determining the true nutri-physiological
328 value of feed ingredients for swine. *Animals*. 2021;11(5):1259. <https://doi.org/10.3390/ani11051259>
- 329 13. Seabolt BV, Van Heugten E, Kim SW, Ange-van Heugten KD, Roura E. Feed preferences and
330 performance of nursery pigs fed diets containing various inclusion amounts and qualities of distillers
331 coproducts and flavor. *J Anim Sci*. 2010;88(11):3725–38. <https://doi.org/10.2527/jas.2009-2640>
- 332 14. Hastad CW. The use of dried distillers grain with solubles in swine diets [doctoral dissertation].
333 Manhattan (KS): Kansas State University; 2005.
- 334 15. O'Reilly K. Effect of condensed molasses solubles on intake, growth performance, digestibility and
335 certain rumen parameters of sheep [master's thesis]. Pretoria (South Africa): University of Pretoria;
336 2017.
- 337 16. Roura E, Fu M. Taste, nutrient sensing and feed intake in pigs (130 years of research: then, now and
338 future). *Anim Feed Sci Technol*. 2017;233:3–12. <https://doi.org/10.1016/j.anifeedsci.2017.08.002>
- 339 17. Oostindjer, M., Bolhuis, J. E., Simon, K., van den Brand, H., & Kemp, B. (2011). Perinatal flavour
340 learning and adaptation to being weaned: all the pig needs is smell. *PLoS One*, 6(10), e25318.
341 <https://doi.org/10.1016/j.anifeedsci.2019.114315>
- 342 18. Xu B, Li Z, Wang C, Fu J, Zhang Y, Wang Y, Lu Z. Effects of fermented feed supplementation on pig
343 growth performance: a meta-analysis. *Anim Feed Sci Technol*. 2020;259:114315.
- 344 19. Tang X, Liu X, Zhang K. Effects of microbial fermented feed on serum biochemical profile, carcass
345 traits, meat amino acid and fatty acid profile, and gut microbiome composition of finishing pigs. *Front*
346 *Vet Sci*. 2021;8:744630. <https://doi.org/10.3389/fvets.2021.744630>
- 347 20. Rao ZX, Tokach MD, Woodworth JC, DeRouche JM, Goodband RD, Gebhardt JT. Effects of various
348 feed additives on finishing pig growth performance and carcass characteristics: a review. *Animals*.
349 2023;13(2):200. <https://doi.org/10.3390/ani13020200>
- 350 21. Ramukanda M. Effects of molasses-enhanced fermentation and exogenous enzymes on the nutritive
351 value of castor bean (*Ricinus communis* L) oil cake for growing pigs [dissertation]. Pietermaritzburg:
352 University of KwaZulu-Natal; 2023.
- 353 22. Eklund M, Mosenthin R, Tafaj M, Wamatu J. Effects of betaine and condensed molasses solubles on
354 nitrogen balance and nutrient digestibility in piglets fed diets deficient in methionine and low in
355 compatible osmolytes. *Arch Anim Nutr*. 2006;60(4):289–300.
356 <https://doi.org/10.1080/17450390600785525>.

- 357 23. Ndlovu T, Chimonyo M, Okoh AI, Muchenje V, Dzama K, Raats JG. Assessing the nutritional status
358 of beef cattle: current practices and future prospects. *Afr J Biotechnol.* 2007;6(24). t
359 <http://www.academicjournals.org/AJB>
- 360 24. Abeni F, Petrera F, Dal Prà A, Rapetti L, Crovetto GM, Galassi G. Blood parameters in fattening pigs
361 from two genetic types fed diet with three different protein concentrations. *Transl Anim Sci.*
362 2018;2(4):372–82. <https://doi.org/10.1093/tas/txy069>
- 363 25. Cho JH, Upadhaya SD, Kim IH. Effects of dietary supplementation of modified zinc oxide on growth
364 performance, nutrient digestibility, blood profiles, fecal microbial shedding and fecal score in weanling
365 pigs. *Anim Sci J.* 2015;86(6):617–23. <https://doi.org/10.1111/asj.12329>
- 366 26. Rezaei R, Knabe DA, Tekwe CD, Dahanayaka S, Ficken MD, Fielder SE, Wu G. Dietary
367 supplementation with monosodium glutamate is safe and improves growth performance in postweaning
368 pigs. *Amino Acids.* 2013;44:911–23. <https://doi.org/10.1007/s00726-012-1420-x>
- 369 27. Fang LH, Jin YH, Do SH, Hong JS, Kim BO, Han TH, Kim YY. Effects of dietary energy and crude
370 protein levels on growth performance, blood profiles, and carcass traits in growing-finishing pigs. *J*
371 *Anim Sci Technol.* 2019;61(4):204. <https://doi.org/10.5187/jast.2019.61.4.204>
- 372 28. Ježek J, Starič J, Nemeč M, Plut J, Oven IG, Klinkon M, Štukelj M. The influence of age, farm, and
373 physiological status on pig hematological profiles. *J Swine Health Prod.* 2018;26(2):72–8.
- 374 29. Han GG, Lee JY, Jin GD, Park J, Choi YH, Kang SK, Choi YJ. Tracing of the fecal microbiota of
375 commercial pigs at five growth stages from birth to shipment. *Sci Rep.* 2018;8(1):6012.
376 <https://doi.org/10.1038/s41598-018-24508-7>
- 377 30. Guo Y, He F, Deng Z, Yin J, Guan G, Xie Z, et al. Dietary serine supplementation improves growth
378 performance, intramuscular fat content, and composition of gut microbes and metabolites in growing–
379 finishing pigs. *Agriculture.* 2024;14(3):349. <https://doi.org/10.3390/agriculture14030349>
- 380 31. Xiong Y, Yi H, Wu Q, Jiang Z, Wang L. Effects of acute heat stress on intestinal microbiota in grow-
381 finishing pigs, and associations with feed intake and serum profile. *J Appl Microbiol.* 2020;128(3):840–
382 52. <https://doi.org/10.1111/jam.14504>
- 383 32. Song D, Chang S, An J, Park S, Jeon K, Kim H, Cho J. Effects of different stocking density in lairage
384 of fattening pigs in high temperatures. *Korean J Agric Sci.* 2023;50(4):861–7.
385 <https://doi.org/10.7744/kjoas.500422>

- 386 33. Chang SY, Lee JH, Oh HJ, An JW, Song DC, Cho HA, Cho JH. Effect of different ratios of phytogetic
387 feed additives on growth performance, nutrient digestibility, intestinal barrier integrity, and immune
388 response in weaned pigs challenged with a pathogenic *Escherichia coli*. J Anim Sci. 2023;101:skad148.
389 <https://doi.org/10.1093/jas/skad148>
- 390 34. Wang T, Yao W, Li J, Shao Y, He Q, Xia J, Huang F. Dietary garcinol supplementation improves
391 diarrhea and intestinal barrier function associated with its modulation of gut microbiota in weaned
392 piglets. J Anim Sci Biotechnol. 2020;11:1–13. <https://doi.org/10.1186/s40104-020-0426-6>
- 393 35. Yan L, Kim IH. Effect of probiotics supplementation in diets with different nutrient densities on growth
394 performance, nutrient digestibility, blood characteristics, faecal microbial population and faecal noxious
395 gas content in growing pigs. J Appl Anim Res. 2013;41:23–8.
396 <https://doi.org/10.1080/09712119.2012.739092>
- 397 36. Zali A, Eftekhari M, Poursad K, Ganjkanlou M, Fatehi F, Zakaria Pour H. Effect of vinasse
398 (condensed molasses solubles) on performance, blood metabolites, ruminal parameters and carcass
399 characteristics of Mahabadi goat male kids. J Anim Feed Sci. 2019;28:321–7.
400 <https://doi.org/10.22358/jafs/112527/2019>
- 401 37. Mordenti AL, Giaretta E, Campidonico L, Parazza P, Formigoni A. A review regarding the use of
402 molasses in animal nutrition. Animals. 2021;11(1):115. <https://doi.org/10.3390/ani11010115>
- 403 38. Cravens WW, Holck GL. Economic benefits to the livestock producer and to the consumer from the
404 use of feed additives. J Anim Sci. 1970;31(6):1102–6. <https://doi.org/10.2527/jas1970.3161102x>
- 405 39. Pienaar GA. The potential of condensed molasses solubles (CMS) to replace molasses in feedlot diets
406 [master's thesis]. Pretoria (South Africa): University of Pretoria; 2016.
- 407 40. Park S, Lee J, Kim S, Kim H, Song D, Chang S, et al. Identifying the optimal ratios for replacing spray-
408 dried plasma protein with hydrolyzed porcine intestinal protein in weaning pig. J Anim Sci Technol.
409 2024. <https://doi.org/10.5187/jast.2024.e120>
- 410 41. Shahini E, Misiuk M, Zakhodym M, Borkovska V, Koval N. Analysis of the economic efficiency of
411 growing pigs for meat and its improvement. Sci Horiz. 2023;26(6):110–20. 10.48077/scihor6.2023.110
- 412 42. Li DH, Kim BG, Lee SR. A respiration-metabolism chamber system for measuring gas emission and
413 nutrient digestibility in small ruminant animals. Rev Colomb Cienc Pecu. 2010;23(4):444–50.
- 414 43. Hansard SL, Plumlee MP, Hobbs CS, Comar CL. The design and operation of metabolism units for
415 nutritional studies with swine. J Anim Sci. 1951;10(1):88–96. <https://doi.org/10.2527/jas1951.10188x>

- 416 44. Karalazos A, Swan H. The nutritional value for sheep of molasses and condensed molasses solubles.
417 Anim Feed Sci Technol. 1977;2:143–52. [https://doi.org/10.1016/0377-8401\(77\)90015-3](https://doi.org/10.1016/0377-8401(77)90015-3)
- 418 45. Navarro DM, Abelilla JJ, Stein HH. Structures and characteristics of carbohydrates in diets fed to pigs:
419 a review. J Anim Sci Biotechnol. 2019;10:1–17. <https://doi.org/10.1186/s40104-019-0345-6>
- 420 46. Knudsen KEB, Hedemann MS, Lærke HN. The role of carbohydrates in intestinal health of pigs. Anim
421 Feed Sci Technol. 2012;173(1–2):41–53. <https://doi.org/10.1016/j.anifeedsci.2011.12.020>
- 422 47. Knudsen KB, Lærke HN, Ingerslev AK, Hedemann MS, Nielsen TS, Theil PK. Carbohydrates in pig
423 nutrition—recent advances. J Anim Sci. 2016;94(Suppl 3):1-11. <https://doi.org/10.2527/jas.2015-9785>
- 424 48. Chen L, Gao LX, Huang QH, Zhong RQ, Zhang LL, Tang XF, Zhang HF. Viscous and fermentable
425 nonstarch polysaccharides affect intestinal nutrient and energy flow and hindgut fermentation in
426 growing pigs. J Anim Sci. 2017;95(11):5054–63. <https://doi.org/10.2527/jas2017.1662>
- 427 49. Hannon K, Trenkle A. Evaluation of condensed molasses fermentation solubles as a nonprotein nitrogen
428 source for ruminants. J Anim Sci. 1990;68(9):2634–41. <https://doi.org/10.2527/1990.6892634x>
- 429 50. Nahm KH. Influences of fermentable carbohydrates on shifting nitrogen excretion and reducing
430 ammonia emission of pigs. Crit Rev Environ Sci Technol. 2003;33(2):165–86.
431 <https://doi.org/10.1080/10643380390814523>
- 432 51. Mavromichalis I, Hancock JD, Hines RH, Senne BW, Cao H. Lactose, sucrose, and molasses in simple
433 and complex diets for nursery pigs. Anim Feed Sci Technol. 2001;93(3–4):127–35.
434 [https://doi.org/10.1016/S0377-8401\(01\)00287-5](https://doi.org/10.1016/S0377-8401(01)00287-5)
- 435 52. Van Der Peet-Schwering CMC, Kemp B, Den Hartog LA, Schrama JW, Verstegen MWA. Adaptation
436 to the digestion of nutrients of a starch diet or a non-starch polysaccharide diet in group-housed pregnant
437 sows. J Anim Physiol Anim Nutr (Berl). 2002;86(11-12), 414-421. <https://doi.org/10.1046/j.1439-0396.2002.00398.x>
- 439 53. Pi Y, Gao K, Peng Y, Mu CL, Zhu WY. Antibiotic-induced alterations of the gut microbiota and
440 microbial fermentation in protein parallel the changes in host nitrogen metabolism of growing
441 pigs. Animal. 2019;13(2), 262-272. <https://doi.org/10.1017/S1751731118001416>
- 442 54. Mansilla WD. Non-protein nitrogen is used efficiently for improving protein deposition and feed
443 efficiency in growing pigs [doctoral dissertation]. Guelph (Canada): University of Guelph; 2013.
- 444

TABLES AND FIGURES

Table 1. Compositions of basal diet (as-fed-basis)¹

Items	Growing period (0–6 W)	Finishing period (6–14 W)
Ingredients, %		
Corn	53.479	53.959
Soybean meal	15.660	15.466
Wheat	3.750	3.750
Rice bran	6.500	6.500
DDGS	11.500	10.500
Limestone	1.270	0.883
Vegetable oil	1.320	2.000
Sugar	4.590	4.950
Poultry oil	0.200	0.200
Salt	0.358	0.378
Choline chloride	0.040	0.066
Lysine sulfate, 78%	0.724	0.731
L-methionine, 99%	0.083	0.128
Tryptophan, 98%	0.049	0.043
Emulsifier	0.050	0.050
MDCP	0.061	-
Threonine, 99%	0.146	0.176
Vitamin & mineral premix ²	0.220	0.220
Total	100.00	100.00
Calculated value		
NE, kcal/kg	2475	2475
CP, %	15.90	14.89
Lysine, %	1.35	0.96
Methionine, %	0.36	0.34
Ca, %	0.72	0.46
P, %	0.49	0.44

¹)DDGS, dried distiller's grains with solubles; MDCP, monocalcium phosphate; CP, crude protein; NE, net energy; Ca, calcium; P, phosphorus.

²)Provided per kilogram of complete diet: vitamin A, 11025 U; vitamin D₃, 1103 U; vitamin E, 44 U; vitamin K, 4.4 mg; riboflavin, 8.3 mg; niacin, 50 mg; thiamine, 4 mg; d-pantothenic, 29 mg; choline, 166 mg; and vitamin B₁₂, 33 µg; Cu (as CuSO₄ · 5H₂O), 12 mg; Zn (as ZnSO₄), 85 mg; Mn (as MnO₂), 8 mg; I (as KI), 0.28 mg; and selenium (as Na₂SeO₃ · 5H₂O), 0.15 mg.

Table 2. Effect of monosodium glutamate-condensed molasses solubles (MSG-CMS) to replace molasses on growth performance in growing-finishing pigs (Exp 1)

Items	PC	NC	T1	T2	T3	SE	<i>p</i> -value
BW, kg							
Initial	23.30	23.20	23.23	23.05	23.05	2.027	1.000
3W	37.95	37.23	38.88	37.88	36.98	2.304	0.980
6W	56.43	54.35	58.63	57.08	53.85	2.109	0.502
10W	83.95	80.55	85.90	84.40	80.95	3.005	0.674
14W	112.53	108.23	114.88	114.15	108.43	2.862	0.349
0–3 W							
ADG, kg	0.70	0.67	0.75	0.71	0.66	0.058	0.858
ADFI, kg	1.62	1.56	1.57	1.57	1.55	0.022	0.200
G:F	0.43	0.43	0.48	0.45	0.43	0.040	0.887
3–6 W							
ADG, kg	0.88	0.82	0.94	0.91	0.80	0.060	0.434
ADFI, kg	2.22 ^a	2.04 ^b	2.19 ^{ab}	2.17 ^{ab}	2.10 ^{ab}	0.033	0.011
G:F	0.40	0.40	0.43	0.42	0.38	0.030	0.810
0–6 W							
ADG, kg	0.79 ^{ab}	0.74 ^b	0.84 ^a	0.81 ^{ab}	0.73 ^b	0.018	0.003
ADFI, kg	1.92 ^a	1.80 ^b	1.88 ^{ab}	1.87 ^{ab}	1.82 ^b	0.018	0.002
G:F	0.41 ^{ab}	0.41 ^{ab}	0.45 ^a	0.43 ^{ab}	0.40 ^b	0.010	0.029
6–10 W							
ADG, kg	0.98	0.94	0.97	0.98	0.97	0.107	0.998
ADFI, kg	2.49	2.43	2.48	2.47	2.46	0.021	0.317
G:F	0.39	0.39	0.39	0.39	0.39	0.043	1.000
10–14 W							
ADG, kg	1.02	0.99	1.03	1.06	0.98	0.054	0.819
ADFI, kg	2.84 ^a	2.64 ^b	2.85 ^a	2.79 ^{ab}	2.73 ^{ab}	0.036	0.005
G:F	0.36	0.38	0.36	0.38	0.36	0.019	0.901
6–14 W							
ADG, kg	1.00	0.96	1.00	1.02	0.97	0.042	0.868
ADFI, kg	2.66 ^a	2.53 ^b	2.67 ^a	2.63 ^{ab}	2.59 ^{ab}	0.023	0.005
G:F	0.38	0.38	0.38	0.39	0.38	0.016	0.985
0–14 W							
ADG, kg	0.91	0.87	0.94	0.93	0.87	0.024	0.190
ADFI, kg	2.29 ^a	2.17 ^c	2.27 ^a	2.25 ^{ab}	2.21 ^{bc}	0.011	<0.001
G:F	0.40	0.40	0.41	0.41	0.39	0.011	0.693

PC, basal diet with 2% molasses; NC, basal diet; T1, basal diet with 1.5% molasses and 0.5% MSG-CMS; T2, basal diet with 1% molasses and 1% MSG-CMS; T3, basal diet with 2% MSG-CMS; BW, body weight; ADG, average daily gain; ADFI, average daily feed intake; G:F, feed efficiency; SE, standard error.

^{a-c} Means with different letters are significantly different ($p < 0.05$).

ACCEPTED

Table 3. Effect of monosodium glutamate-condensed molasses solubles (MSG-CMS) to replace molasses on nutrient digestibility in growing-finishing pigs (Exp 1)

Items, %	PC	NC	T1	T2	T3	SE	<i>p</i> -value
6W							
DM	86.08	85.88	86.75	87.08	87.02	0.533	0.411
CP	68.41	67.12	68.56	69.09	69.05	0.615	0.206
GE	78.29	78.72	80.42	78.15	77.40	1.105	0.420
10W							
DM	86.87	85.15	86.16	86.62	85.74	0.968	0.730
CP	70.69	69.90	70.55	71.48	71.13	0.743	0.635
GE	78.49	78.40	79.12	78.45	77.20	0.980	0.732
14W							
DM	86.54	85.83	85.75	87.98	87.17	0.913	0.410
CP	70.67	70.12	70.31	72.03	71.51	0.564	0.133
GE	80.46	78.08	79.28	81.22	80.44	0.813	0.109

PC, basal diet with 2% molasses; NC, basal diet; T1, basal diet with 1.5% molasses and 0.5% MSG-CMS; T2, basal diet with 1% molasses and 1% MSG-CMS; T3, basal diet with 2% MSG-CMS; DM, dry matter; CP, crude protein; GE, gross energy; SE, standard error.

Table 4. Effect of monosodium glutamate-condensed molasses solubles (MSG-CMS) to replace molasses on blood profiles in growing-finishing pigs (Exp 1)

Items	PC	NC	T1	T2	T3	SE	<i>p</i> -value
6W							
WBC, 10 ⁶ /μl	17.90	17.06	17.40	17.89	16.98	0.369	0.273
RBC, 10 ³ /μl	7.05	6.33	6.76	7.31	6.75	0.307	0.271
TP, g/dL	6.28	5.69	6.11	6.12	6.30	0.298	0.616
BUN, mg/dL	10.50	9.84	10.18	10.80	9.88	0.617	0.776
Lymphocyte, %	53.61	51.41	53.02	54.40	54.85	1.839	0.714
Neutrophil, %	34.23	34.40	35.09	34.43	33.70	1.257	0.956
Eosinophil, %	1.62	1.54	1.54	1.64	1.53	0.168	0.980
Monocyte, %	4.57	5.41	4.40	4.85	4.44	0.403	0.410
10W							
WBC, 10 ⁶ /μl	19.86	19.69	18.98	19.16	19.55	0.405	0.533
RBC, 10 ³ /μl	7.03	7.16	6.87	6.78	6.96	0.227	0.795
TP, g/dL	5.98	5.96	6.11	5.81	5.72	0.311	0.909
BUN, mg/dL	10.59	10.45	11.04	11.03	11.15	0.546	0.857
Lymphocyte, %	55.62	51.64	52.42	55.02	55.30	2.190	0.604
Neutrophil, %	35.89	35.22	36.35	33.29	34.63	1.868	0.801
Eosinophil, %	1.56	1.32	1.48	1.38	1.55	0.155	0.745
Monocyte, %	3.92	4.76	5.15	3.62	4.52	0.407	0.103
14W							
WBC, 10 ⁶ /μl	19.26	20.99	19.28	20.26	21.33	0.942	0.428
RBC, 10 ³ /μl	7.48	7.07	7.33	6.92	6.91	0.286	0.551
TP, g/dL	5.83	6.20	6.37	5.98	6.07	0.345	0.825
BUN, mg/dL	12.68	11.58	11.70	12.60	11.37	0.477	0.219
Lymphocyte, %	50.07	51.22	51.63	55.55	52.67	2.105	0.451
Neutrophil, %	37.70	35.19	35.93	32.85	34.94	1.709	0.412
Eosinophil, %	1.59	1.31	1.43	1.76	1.43	0.131	0.187
Monocyte, %	4.81	4.67	4.63	4.90	4.53	0.490	0.984

PC, basal diet with 2% molasses; NC, basal diet; T1, basal diet with 1.5% molasses and 0.5% MSG-CMS; T2, basal diet with 1% molasses and 1% MSG-CMS; T3, basal diet with 2% MSG-CMS; WBC, white blood cell; RBC, red blood cell; TP, total protein; BUN, blood urea nitrogen; SE, standard error.

Table 5. Effect of monosodium glutamate-condensed molasses solubles (MSG-CMS) to replace molasses on fecal microbial in growing-finishing pigs (Exp 1)

Items, log CFU/g	PC	NC	T1	T2	T3	SE	<i>p</i> -value
6W							
<i>E. coli</i>	6.79	6.50	6.39	6.50	6.58	0.144	0.389
<i>Lactobacillus</i>	7.92	7.86	8.08	8.26	8.06	0.276	0.859
10W							
<i>E. coli</i>	6.50	6.45	6.46	6.54	6.62	0.188	0.967
<i>Lactobacillus</i>	8.54	8.12	8.11	7.91	7.93	0.334	0.680
14W							
<i>E. coli</i>	6.42	6.44	6.22	6.39	6.66	0.159	0.458
<i>Lactobacillus</i>	8.11	8.15	8.39	8.20	8.29	0.267	0.948

PC, basal diet with 2% molasses; NC, basal diet; T1, basal diet with 1.5% molasses and 0.5% MSG-CMS; T2, basal diet with 1% molasses and 1% MSG-CMS; T3, basal diet with 2% MSG-CMS; CFU, colony forming unit; SE, standard error.

450

ACCEPTED

Table 6. Effect of monosodium glutamate-condensed molasses solubles (MSG-CMS) to replace molasses on economic efficiency in growing-finishing pigs (Exp 1)

Items	PC	NC	T1	T2	T3	SE	<i>p</i> -value
0–6 W							
TWG, kg/pig	33.13 ^{ab}	31.15 ^b	35.40 ^a	34.03 ^{ab}	30.80 ^b	0.755	0.003
TFI, kg/pig	80.69 ^a	75.71 ^b	78.91 ^{ab}	78.49 ^{ab}	76.44 ^b	0.765	0.002
FCG, ¥/kg gain	1209 ^a	1187 ^{ab}	1105 ^b	1142 ^{ab}	1226 ^a	27.996	0.045
6–14 W							
TWG, kg/pig	56.10	53.88	56.25	57.08	54.58	2.360	0.868
TFI, kg/pig	149.17 ^a	141.89 ^b	149.24 ^a	147.21 ^{ab}	145.25 ^{ab}	1.268	0.005
FCG, ¥/kg gain	1340	1312	1338	1310	1346	59.177	0.988
0–14 W							
TWG, kg/pig	89.23	85.03	91.65	91.10	85.38	2.357	0.190
TFI, kg/pig	224.67 ^a	212.48 ^c	222.64 ^a	220.38 ^{ab}	216.27 ^{bc}	1.029	<0.001
FCG, ¥/kg gain	1260	1233	1215	1211	1267	35.625	0.728

PC, basal diet with 2% molasses; NC, basal diet; T1, basal diet with 1.5% molasses and 0.5% MSG-CMS; T2, basal diet with 1% molasses and 1% MSG-CMS; T3, basal diet with 2% MSG-CMS; TWG, total weight gain; TFI, total feed intake; FCG, feed cost per gain; SE, standard error.

^{a-c} Means with different letters are significantly different ($p < 0.05$).