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ORIGINAL PAPER

Dietary glucose oxidase supplementation improves growth performance, antioxidative capacity, and meat quality in finishing pigs

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Abstract. The purpose of this study was to assess the effects of dietary supplementation with glucose oxidase (GOX) on growth performance, faecal microbial populations, meat quality, faecal gas emissions, apparent nutrient digestibility, and serum antioxidant enzyme parameters in finishing pigs. A total of 200 finishing pigs [(Landrace × Yorkshire) × Duroc] were used in a 70-day trial. The pigs were randomly assigned to 4 groups based on their initial body weight (52.69 ± 0.58 kg) and sex. Each treatment consisted of 10 replicate pens with five pigs (gilts and barrows) per pen. The dietary treatments included a control diet and the control diet supplemented with 0.01, 0.02, or 0.03% GOX. The results showed linear increases in average daily gain ($P = 0.038$), average daily feed intake ($P = 0.039$), serum glutathione peroxidase activity ($P = 0.009$), and serum glutathione concentration ($P = 0.005$) with increasing dietary GOX

supplementation. In contrast, drip loss on day 7 decreased linearly ($P = 0.014$) with the lowest value observed in pigs receiving 0.03% GOX. In conclusion, dietary supplementation with 0.03% GOX improved growth performance and meat quality likely by increasing antioxidant enzyme levels in a dose-dependent manner.

Key words: antioxidant, glucose oxidase, growth performance, finishing pigs, meat quality

Introduction

Exogenous dietary enzyme supplementation is a common strategy to improve nutrient digestibility in animals. These enzymes interact with anti-nutritional factors in feed, increasing the availability of nutrients for absorption in the intestine (Gaines et al., 2018; Munezero and Kim, 2022). Some exogenous enzymes may resist degradation in the stomach and remain biologically active in the intestine, thus improving the intestinal environment (Zou et al., 2019). Exogenous enzymes that enhance intestinal health may have greater application potential in swine nutrition than conventional feed enzymes (Gaines et al., 2018). Dietary supplementation with lysozyme, lactoperoxidase, or protease has been reported to alleviate intestinal disorders, thereby improving the growth performance in pigs (Oliver and Wells, 2015; Park et al., 2020). Recently, glucose oxidase (GOX) has attracted considerable attention as a functional feed enzyme (Wang et al., 2018; Zhao et al., 2022; Zhao et al., 2023). It is an aerobic dehydrogenase that catalyses the oxidation of β-D-glucose to gluconic acid and produces hydrogen peroxide as a by-product (Bankar et al., 2009; Wang et al., 2022a). Hydrogen peroxide has been suggested to play a role in the regulation of intestinal microbial populations (Shigeno et al., 2019). Because intestinal health is closely associated with animal performance, factors that influence gut function may also affect growth and productivity (Pluske et al., 2018). It has been reported that GOX shows a range of biological

properties, including antimicrobial effects (Zhao et al., 2014), alleviation of oxidative stress (Cruz et al., 2012), enhancement of immune function (Wang et al., 2018), and mitigation of intestinal mycotoxin toxicity (Tang et al., 2015). Previous studies have demonstrated that feeding weaning pigs with a GOX-containing diet could improve growth performance by regulating intestinal microbiota communities (Tang et al., 2016; Tang et al., 2013; Tian et al., 2012). In addition, GOX has been reported to play an important role in enhancing the antioxidant capacity in weaned pigs (Zhang et al., 2020; Dang et al., 2021a,b). Hou et al. (2017) demonstrated that GOX supplementation increased apparent nutrient digestibility in weaned pigs, which was associated with reduced intestinal stress and improved serum antioxidant status. In the modern swine industry, reducing faecal noxious gas emission is important not only for animal health and welfare but also for supporting sustainable agricultural practices (Mehrabi et al., 2020). Research has indicated that improving nutrient digestibility through the regulation of intestinal microbial communities is an effective strategy for reducing faecal noxious gas emissions (Nahm et al., 2002). Because nutrient digestibility and microbial fermentation are closely linked to faecal gas production, improvements in intestinal function may also influence environmental emissions. Most of the beneficial effects of GOX have been demonstrated in weaned piglets, whereas evidence in finishing pigs remains limited. Moreover, its potential effects on faecal gas emission have not been well characterised, highlighting the need for studies in older animals. We hypothesised that dietary supplementation with GOX would improve growth performance and meat quality in finishing pigs by optimising faecal microbial populations and/or serum antioxidant enzyme levels, thereby reducing faecal noxious gas emission.

Therefore, the aim of this study was to evaluate the effects of dietary GOX supplementation on growth performance, faecal characteristics, antioxidant status, and meat quality in finishing pigs.

Material and methods

All animal procedures were approved by the Dankook University Institutional Animal Care and Use Committee (approval No. DK-1-1965) and were conducted in accordance with ethical and humane principles for the use of animals in research.

Glucose oxidase (GOX)

The commercial GOX preparation (Bestzyme Bio-engineering Co., LTD; Jinan, China) was derived from a heterologous expression system involving *Aspergillus niger*. In accordance with the manufacturer's specifications, the optimum temperature range for GOX activity is 20–80 °C and the optimum pH range is 2.0–7.0. The enzyme activity is 1000 units/g. One unit of GOX activity is defined as the amount of enzyme that oxidises 1 micromole of β-D-glucose per minute to hydrogen peroxide and D-gluconic acid at 37 °C and pH 5.5.

Experimental animals and housing

A total of 200 crossbred finishing pigs [(Landrace × Yorkshire) × Duroc], with an initial body weight of 52.69 ± 0.58 kg, were allocated to four treatment groups based on body weight and sex. Each treatment comprised 10 replicate pens with 5 pigs per pen, with gilts and barrows distributed evenly among treatments. The dietary treatments were as follows: 1) basal maize-soybean meal diet containing 3300 kcal/kg and 14% crude protein, without additives (CON), 2) basal diet with 0.01% GOX (GOX1), 3) basal diet with 0.02% GOX (GOX2), and 4) basal diet with 0.03% GOX (GOX3). The diets were formulated to meet or slightly exceed the nutrient requirements for swine recommended by the National Research Council (Table 1) (NRC, 2012). Before the experimental period, all pigs were fed the basal diet for 14 days to allow adaptation to the housing and feeding conditions.

During the experimental period, all pigs were housed in an environmentally controlled facility. The ambient temperature and relative humidity were maintained at 24 °C and 60%, respectively. The room was mechanically ventilated, and the pens had plastic slatted floors. Each pen measured 1.43 m × 1.67 m. A nipple drinker and a stainless-steel self-feeder were installed in each pen to provide *ad libitum* access to water and feed, respectively.

Sample collection and measurements

Growth performance

All pigs were weighed individually on days 1 and 70 to calculate average daily gain (ADG). Feed consumption was recorded daily on a pen basis to calculate average daily feed intake (ADFI). The feed conversion ratio (FCR) was calculated using ADG and ADFI values.

Apparent total tract digestibility

During days 63–70, 0.20% chromium oxide was added to all diets to determine the apparent total tract digestibility (ATTD) of dry matter (DM), nitrogen (N), and energy (E). On day 69, fresh faecal samples were collected from two randomly selected pigs per pen by rectal massage. Feed samples were collected after mixing of the diets. Feed and faecal samples were dried in a forced-air oven at 70 °C for 72 h, then ground and passed through a 1-mm sieve. The DM (method 930.15) and N (method 968.06) contents of the feed and faecal samples were analysed according to AOAC (2000) procedures. A bomb calorimeter (Parr 6100; Parr Instrument Co., Moline, IL, USA) was utilised to evaluate the E content of faecal and feed samples. Ultraviolet absorption spectrophotometry (UV-1201, Shimadzu, Kyoto, Japan) was used to analyse chromium content. The analysis of ATTD was calculated according to the method described by Munezero et al. (2022).

Faecal gas emission and faecal microbiota analysis

On day 70, fresh faecal samples (approximately 350 g) were collected by rectal massage from

two randomly selected pigs per pen for the determination gas emissions and microbial composition. Faecal samples were pooled on a pen basis. For each pen, the pooled sample was divided into subsamples, with one portion used for microbiota analysis and the other portion for gas emission measurements.

For microbial determinations, approx. 15 g of fresh faeces was promptly transported on ice to the laboratory. A composite faecal sample (approx. 1 g) from each pen was serially diluted in 9 ml of 1% peptone broth (Becton, Dickinson and Co., Franklin Lakes, NJ, USA). Ten-fold serial dilutions were prepared, and appropriate dilutions were plated on MacConkey agar (Difco Laboratories, Detroit, MI) for enumeration of coliform bacteria and on Lactobacilli medium III agar (Medium 638, DSMZ, Braunschweig, Germany) for enumeration of lactic acid bacteria. MacConkey plates were incubated aerobically at 37 °C for 24 h, whereas Lactobacilli Medium III agar plates were incubated anaerobically at 39 °C for 48 h. Following incubation, colonies characteristic of coliforms and lactic acid bacteria were counted and expressed as colony-forming units (CFU) per g of faeces.

The remaining faecal samples (approx. 300 g) were placed in 2.6 l sealed containers equipped with a small opening on one side, which was covered with adhesive tape, and fermented at 25 °C for 24 h. After fermentation, the contents of each container were manually mixed for 30 s for homogenisation. Gas samples were then collected by inserting a gas-sampling pump (model GV-100S; Gastec Corp., Japan) through the opening in the container. Ammonia (NH_3) and total mercaptan concentrations were measured using Gastec detector tubes No. 3La and No. 70L, respectively. The measurement ranges were 5.0–100.0 ppm for NH_3 and 2.0–20.0 ppm for total mercaptans. Two valid measurements were obtained from each container, and the mean value was used for statistical analysis.

Serum antioxidant enzyme analysis

On day 70, blood samples were collected from two randomly selected pigs per pen by anterior vena cava puncture between 11:00 to 12:00 and transferred to non-heparinised vacuum tubes. Blood glucose concentration was determined using an automatic biochemical analyser (HITACHI 747; Hitachi, Tokyo, Japan). The blood samples were then centrifuged at 3 000 × g for 15 min at 4 °C to obtain serum samples. Serum glutathione peroxidase (GPX) activity, glutathione (GSH) concentration, and superoxide dismutase (SOD) activity were measured immediately according to the method described by Dang et al. (2020).

Carcass characteristics analysis

At the end of the trial, the pigs were transported to a commercial slaughterhouse under standard industrial conditions. The animals were electrically stunned and subsequently subjected to exsanguination, scalding, and dehairing according to routine commercial procedures. Carcass weight was measured after exsanguination and evisceration. At 45 min post mortem, carcass backfat thickness was measured using a real-time ultrasound device (Piglot 105; SFK Technology, Herlev, Denmark).

Meat quality analysis

According to the ear tag identification, loin samples from the right side of the carcass between the 10^{th} and 11^{th} ribs were collected from two randomly selected pigs per pen. After chilling at 2 °C for 24 h, meat quality characteristics were evaluated at ambient temperature (25 °C). Subjective muscle colour and firmness were assessed using a six-point scale (1 = pale pinkish-grey to white, soft to 6 = dark, purplish-red, very firm; NPPC, 2000), whereas marbling was evaluated using a five-point scale (1 = devoid of marbling to 5 = moderately abundant marbling or greater; NPPC, 1991). Lightness (L*), redness (a*), and yellowness (b*) values were measured using a CR-410 Chroma

Meter (Konica Minolta Sensing, Inc., Osaka, Japan). Measurements were taken at three locations on the surface of each sample, and the mean value was calculated. Muscle pH was measured at three different locations on the surface of each sample using a pH meter (Pittsburgh, PA, USA), and the average value was recorded. Water-holding capacity (WHC) was determined using the Grau–Hamm press method. Briefly, a 0.3 g of a meat sample was placed on a 125 mm diameter filter paper and pressed between two Plexiglass plates at 3000 psi for 3 min. The WHC was calculated using a digitising area-line sensor (MT-10S; M.T. Precision Co. Ltd., Tokyo, Japan). For determination of cooking loss, a 5 g meat sample was placed in a plastic bag and heated in a water bath (100 °C) for 5 min. The samples were the allowed to cool at ambient temperature. Cooking loss was calculated as follows:

$$Cooking\ loss\ = \frac{sample\ weight\ before\ cooking\ -\ sample\ weight\ after\ cooking}{sample\ weight\ before\ cooking} \times 100.$$

Approximately 2 g of each meat sample was used to determine drip loss using the plastic bag method. Drip loss was measured on days 1, 3, 5, and 7 of chilled storage. Two meat samples (2.5 cm × 2.5 cm) were weighed, placed in drip loss tubes (C. Christensen Laboratory, Hillerød, Denmark) and stored at 2 °C. On days 1, 3, 5, and 7, the samples were removed from the tubes, gently blotted dry with paper towels, and weighed. Drip loss was calculated from the difference between the initial and final sample weights.

Statistical analysis

Data were analysed using the General Linear Model (GLM) procedure of SAS (SAS Institute Inc., Cary, NC, USA) in a randomised complete block design. The pen was considered the experimental unit. Linear, quadratic, and cubic responses to increasing dietary GOX supplementation were evaluated using orthogonal polynomial contrasts. The following statistical model was used:

$$Y_{ij} = \mu + T_i + e_{ij},$$

where: Y_{ij} – observed response variable, μ – overall mean, T_i – fixed effect of treatment, and e_{ij} – residual error. Differences were considered significant at $P < 0.05$. Data variability is presented as the standard error of the mean (SEM).

Results

Table 2 presents the effects of dietary GOX supplementation effects on growth performance and nutrient digestibility in finishing pigs. Incrementing dietary GOX levels linearly increased ADG ($P = 0.038$) and ADFI ($P = 0.039$), with the highest values observed in pigs receiving 0.03% GOX compared with those fed the basal diet. However, GOX supplementation had no effect on FCR or the apparent total tract digestibility of DM, N, and E.

No differences were observed in faecal counts of lactic acid bacteria or coliform bacteria among the treatment groups. In addition, increasing dietary GOX supplementation did not affect faecal ammonia or total mercaptan concentrations in finishing pigs ($P > 0.05$) (Table 3).

Dietary GOX supplementation affected selected serum antioxidant enzyme parameters in finishing pigs (Table 4). Serum GPX ($P = 0.009$) and GSH ($P = 0.005$) concentrations increased linearly with increasing dietary GOX levels. In contrast, blood glucose and SOD concentrations were not affected by GOX supplementation. Pigs fed the diet containing 0.03% GOX exhibited higher serum GPX and GSH concentrations than those in the other treatment groups.

Supplementing GOX to the diet of finishing pigs did not affect meat lightness, redness, yellowness, colour, marbling, firmness, cooking loss, pH, WHC, carcass weight, or backfat thickness. However, drip loss on day 7 decreased as dietary GOX levels increased ($P = 0.014$). Pigs fed diets containing 0.02 and 0.03% GOX had lower drip loss on day 7 than those fed the basal diet (Table 5).

Discussion

This study confirmed that dietary supplementation with 0.03% GOX improved the growth performance of finishing pigs. Similarly, Wu et al. (2015) reported that feeding weaned pigs diets with 0.02, 0.03, or 0.04% GOX improved ADG, while Tang et al. (2013) observed increased ADG and ADFI in weaned pigs fed diets containing 0.01, 0.02, or 0.04 % GOX. Moreover, a recent study by Wang et al. (2022b) showed that dietary supplementation with GOX at 200 g/t improved ADG in piglets challenged with enterotoxigenic *Escherichia coli* (ETEC) compared to a positive control group without GOX supplementation. Chen et al. (2015) suggested that supplementation with 0.02 % GOX could enhance the growth performance of weaned pigs by regulating intestinal microbiota communities.

The composition and abundance of intestinal microbial communities have a direct effect on the health and growth of pigs (Liu et al., 2019). GOX has been reported to regulate intestinal microbial communities through its unique biological activity, as it oxidises glucose to gluconic acid while producing hydrogen peroxide, thereby altering the intestinal environment (Yu et al., 2017). Therefore, blood glucose concentration has been proposed as a sensitive indicator of GOX activity in the intestine (Chukwuma et al., 2018). However, in the present study, dietary GOX supplementation did not affect faecal counts of coliform bacteria and lactic acid bacteria, nor did it affect blood glucose concentrations in finishing pigs. Similarly, Tang et al. (2016) reported that supplementation with 0.016% GOX did not affect faecal lactic acid bacteria and coliform counts or blood glucose concentrations in weaned pigs. The lack of changes in blood glucose concentration may indicate limited biological activity of GOX in the intestine, which could also explain the absence of effects on the faecal microbiota. Wu et al. (2020) found that GOX derived from different sources exerted distinct effects on intestinal microbial communities. In addition, Wang et al. (2022b)

reported that the positive effects of GOX on intestinal microbiota were dose-dependent. Therefore, the absence of changes in the faecal microbiota observed in the present study may have been due to the relatively low inclusion levels of *Aspergillus niger*-derived GOX (0.01%, 0.02%, and 0.03%). Further studies using higher dietary GOX concentrations are needed to evaluate its effects on the faecal microbiota of finishing pigs.

Long et al. (2021) reported that supplementation with exogenous enzymes can increase serum antioxidant status and contribute to better growth performance in pigs. Previous studies have also shown that GOX can increase the activity of antioxidant enzymes in serum (Wu et al., 2019; Wang et al., 2018; Qu and Liu, 2021). Mu et al. (2018) have argued that GOX plays an important role in improving the antioxidant capacity in weaned pigs. In the present study, pigs fed the diet supplemented with 0.03 % GOX had higher serum GSH and GPX concentrations. The levels of antioxidant enzymes in the body are vital to the health of animals. Reduced antioxidant enzyme activity is associated with oxidative stress, which may lead to physiological and behavioural changes and, consequently, impaired growth performance (Yuan et al., 2007). Conversely, higher antioxidant enzyme concentrations indicate reduced oxidative stress (Dang and Kim 2021). GPX and GSH are the main components of the antioxidant defence system in mammals and help remove reactive oxygen species. By limiting oxidative damage, they reduce the risk of adverse physiological and behavioural effects associated with oxidative stress and may support growth performance (Yuan et al., 2007; Silva-Guillen et al., 2020). Several studies have demonstrated associations between increased serum antioxidant enzyme activities and improved growth performance in pigs (Hu et al., 2017; Silva-Guillen et al., 2020; Qu and Liu, 2021). Therefore, the higher growth performance observed in pigs supplemented with GOX may be related to the increased serum concentrations of antioxidant enzymes.

In addition, Tang et al. (2016) reported that feeding weaned pigs a diet containing 0.016% GOX increased serum growth hormone levels. Further experiments are needed to verify the effects of GOX on serum growth hormones and to clarify the endocrine mechanism underlying its effects on production outcomes in finishing pigs.

Apparent nutrient digestibility is influenced by intestinal microbial communities (Zhang et al., 2014). A greater abundance of beneficial bacteria and a smaller population of potentially harmful bacteria are associated with higher nutrient digestibility (Zhang et al., 2014). Chen et al. (2015) reported that supplementation with 0.02 % GOX increased caecal lactic acid bacteria counts and decreased the number of caecal coliform bacteria, thus improving apparent nutrient digestibility. Wang et al. (2019) and Liu et al. (2020) also suggested the strategy for improving apparent nutrient digestibility by regulating faecal microbial composition. However, in the present study, dietary supplementation with GOX did not affect the faecal microbiota in finishing pigs. This may explain the lack of response in apparent nutrient digestibility.

Emissions of faecal harmful gases can adversely affect the livestock-house environment and, consequently, animal health and productivity. Dang et al. (2020) reported that reducing faecal gas emissions may be achieved through increased nutrient digestibility. Noxious gases are produced during the microbial fermentation of undigested nutrients in the intestinal tract (Ferket et al., 2002). According to Liu et al. (2020), higher nutrient digestibility reduces the amount of substrate available for microbial fermentation, thereby decreasing faecal gas emissions. However, nutrient digestibility was not affected by GOX supplementation in the present experiment, which may explain the lack of effects on faecal gas emissions.

Meat colour, sensory characteristics, cooking loss, WHC, and drip loss are important indicators of meat quality and influence consumer acceptance. Meat pH reflects muscle acid content

(Rosenvold and Andersen 2003) and changes in meat pH can affect cooking loss (Zhang et al., 2011), meat colour (Yu et al., 2010), sensory characteristics (Bidner et al., 2004), WHC (Zhang et al., 2011), and drip loss (Castellini et al., 2002).In the current study, supplementing GOX to the diet of finishing pigs had no effects on meat quality traits although pigs fed the diet containing 0.03% GOX showed lower drip loss. Because meat pH was not affected by GOX supplementation, the reduction in drip loss was unlikely to be related to changes in pH. The lack of changes in meat pH may also explain why meat colour, sensory characteristics, cooking loss, and WHC were unaffected. Previous studies have shown that oxidative processes in meat can influence drip loss. Oxidation alters the formation of hydrogen, electrostatic, and capillary interactions between protein and water molecules, which can increase drip loss (Traore et al., 2012). Higher circulating concentrations of antioxidant enzymes may help reduce oxidative processes in meat after slaughter, thereby decreasing drip loss (Ma et al., 2010). Similarly, Zou et al. (2016) reported that increased serum antioxidant enzyme concentrations were associated with lower drip loss in finishing pigs. In the present study, serum GPX and GSH concentrations were higher in pigs fed the diet supplemented with GOX. Therefore, the reduction in drip loss was likely due to the higher serum antioxidant enzyme concentrations, which could have reduced oxidative reactions in the meat and helped maintain more stable interactions between proteins and water. Lower drip loss decreases weight loss during storage and marketing, and thus the economic losses for retailers. It also limits the accumulation of fluid in meat packaging, which may increase consumer acceptance of pork products (Ngapo et al., 2007).

Conclusions

The results of this study indicate that dietary supplementation with 0.03% glucose oxidase (GOX) (1000 unit/g) increases serum antioxidant enzyme concentrations and is associated with

higher growth performance and lower meat drip loss in finishing pigs. Improved growth performance may contribute to greater production efficiency, whereas reduced drip loss may increase the market value of pork. Among the inclusion levels evaluated, supplementation with 0.03% GOX resulted in higher average daily gain and average daily feed intake, as well as lower drip loss compared to the other treatments. Under the conditions of this study, 0.03% GOX was the most effective dose. However, further studies are required to confirm its applicability under different production environments.

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Data Availability Statement

The data that support this study will be shared upon reasonable request by the corresponding author.

Conflict of interest

The Authors declare that there is no conflict of interest.

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Table 1. Experimental diet compositions (as fed-basis)

Items	CON	GOX1	GOX2	GOX3
Ingredients, %				
corn	76.83	76.82	76.79	76.78
soybean meal	15.30	15.30	15.30	15.30
tallow	2.49	2.49	2.51	2.51
molasses	2.00	2.00	2.00	2.00
dicalcium phosphate	1.35	1.35	1.35	1.35
limestone	0.56	0.56	0.56	0.56
salt	0.30	0.30	0.30	0.30
methionine (99%)	0.07	0.07	0.07	0.07
lysine	0.48	0.48	0.48	0.48
threonine (99%)	0.14	0.14	0.14	0.14
tryptophan (99%)	0.05	0.05	0.05	0.05
choline (25%)	0.03	0.03	0.03	0.03
mineral mix[1]	0.20	0.20	0.20	0.20
vitamin mix[2]	0.20	0.20	0.20	0.20
glucose oxidase	-	0.01	0.02	0.03
total	100.00	100.00	100.00	100.00
Calculated value, %				
metabolizable energy, kcal/kg	3300	3300	3300	3300
crude protein	14.00	14.00	14.00	14.00
calcium	0.60	0.60	0.60	0.60
phosphorus	0.55	0.55	0.55	0.55
lysine	1.00	1.00	1.00	1.00
methionine	0.30	0.30	0.30	0.30
threonine	0.65	0.65	0.65	0.65
tryptophan	0.20	0.20	0.20	0.20
fat	5.35	5.35	5.37	5.37
ash	4.36	4.36	4.36	4.36
fibre	2.34	2.34	2.34	2.34

CON – basal diet, GOX1 – basal diet + 0.01% glucose oxidase, GOX2 – basal diet + 0.02% glucose oxidase, GOX3 – basal diet + 0.03% glucose oxidase;

[1] provided per kg of diet: mg: Fe as ferrous sulphate 115, Cu as copper sulphate 70, Mn as manganese oxide 20, Zn as zinc oxide 60, I as potassium iodide 0.5, Se as sodium selenite 0.3;

[2] provided per kg of diet: IU: vit. A 13 000, vit. D_3 1 700, vit. E 60; mg: vit. K_3 5, vit. B_1 4.2, vit B_2 19, vit. B_6 6.7, vit. B_{12} 0.05, biotin 0.34, folic acid 2.1, niacin 55, D-calcium pantothenate 45

Table 2. Effect of dietary supplementation of glucose oxidase (GOX) on growth performance and apparent nutrient digestibility in finishing pigs

	GOX, %					*P*-value		
Items	0.00	0.01	0.02	0.03	SEM	linear	quadratic	cubic
Growth performance								
ADG, g	851.97[b]	863.74[ab]	878.89[ab]	885.49[a]	12.078	0.038	0.832	0.827
ADFI, g	2562.63[b]	2571.66[ab]	2588.40[ab]	2603.83[a]	14.676	0.039	0.829	0.891
FCR	3.02	2.98	2.95	2.95	0.048	0.267	0.757	0.940
Apparent nutrient digestibility								
dry matter	71.91	72.99	73.87	73.71	0.901	0.131	0.495	0.834
nitrogen	69.18	71.19	69.67	71.01	0.881	0.323	0.706	0.116
energy	70.79	72.37	71.31	72.93	0.897	0.191	0.982	0.198

[v]alues represent the means of ten pens (n = 10) per treatment for growth performance and ten pens with 2 pigs per replicate pen (n = 10) per treatment for apparent nutrient digestibility; ADG – average daily gain, ADFI – average daily feed intake, FCR – feed conversion ratio, SEM – standard error of the mean;
[ab] Means with different superscripts in the same row are significantly different at $P < 0.05$
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Table 3. Effect of dietary supplementation of glucose oxidase (GOX) on faecal microbiota and faecal gas emission in finishing pigs

	GOX, %					*P*-value		
Items, ppm	0.00	0.01	0.02	0.03	SEM	linear	quadratic	cubic
Faecal microbiota								
coliform bacteria	7.12	7.20	7.14	7.17	0.044	0.594	0.533	0.253
lactic acid bacteria	8.97	8.98	9.01	9.04	0.049	0.331	0.873	0.949
Faecal gas emission								
ammonia	3.13	3.00	3.13	2.75	0.459	0.635	0.790	0.721
total mercaptan	5.00	4.89	5.00	4.13	0.302	0.089	0.238	0.373

values represent the means of ten pens with 2 pigs per replicate pen (n = 10) per treatment; SEM – standard error of the mean, $P > 0.05$ (not statistically significant)

Table 4. Effect of dietary supplementation of glucose oxidase (GOX) on serum antioxidant enzyme parameters in finishing pigs

	GOX, %					*P*-value		
Items	0.00	0.01	0.02	0.03	SEM	linear	quadratic	cubic
Glucose, mg/dl	92.25	93.75	95.75	94.00	2.615	0.547	0.546	0.723
Superoxide dismutase, U/ml	0.75	0.89	0.76	0.80	0.074	0.964	0.530	0.215
Glutathione peroxidase, µmol/l	9.35^{b}	9.29^{b}	10.05^{b}	13.43^{a}	1.038	0.009	0.109	0.701
Glutathione, ug/µl	0.87^{b}	0.86^{b}	1.00^{ab}	1.09^{a}	0.058	0.005	0.422	0.405

values represent the means of ten pens with 2 pigs per replicate pen (n = 10) per treatment; SEM – standard error of the mean; ^{ab} means with different superscripts in the same row are significantly different at $P < 0.05$

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Table 5. Effect of dietary supplementation of glucose oxidase (GOX) on meat quality and carcass traits in finishing pigs

	GOX, %					*P*-value		
Items	0.00	0.01	0.02	0.03	SEM	linear	quadratic	cubic
Meat colour								
lightness	48.52	46.98	47.59	47.52	0.572	0.371	0.224	0.291
redness	14.40	14.44	14.19	14.26	0.177	0.408	0.917	0.457
yellowness	4.29	4.09	4.36	4.23	0.122	0.893	0.811	0.136
Sensory evaluation								
colour	3.25	3.31	3.19	3.31	0.097	0.888	0.753	0.334
marbling	3.34	3.25	3.22	3.19	0.154	0.481	0.842	0.929
firmness	3.22	3.13	3.19	3.16	0.143	0.848	0.830	0.702
Cooking loss, %	31.96	33.08	32.47	32.86	0.912	0.615	0.695	0.517
pH	5.52	5.50	5.48	5.54	0.034	0.796	0.209	0.664
Water-holding capacity, %	53.88	52.78	56.75	54.62	3.856	0.725	0.896	0.529
Drip loss, %								
day 1	7.95	7.61	7.40	7.85	0.231	0.626	0.114	0.624
day 3	14.78	14.57	14.07	14.70	1.086	0.883	0.706	0.776
day 5	19.70	19.17	18.97	19.43	0.284	0.441	0.107	0.814
day 7	24.53[a]	24.35[ab]	23.75[b]	23.77[b]	0.233	0.014	0.678	0.339
Carcass weight, kg	90.14	91.04	90.22	91.30	0.922	0.520	0.922	0.381
Carcass backfat thickness, mm	18.26	18.70	18.42	19.62	0.602	0.160	0.528	0.415

values represent the means of ten pens with 2 pigs per replicate pen (n = 10) per treatment for meat colour, sensory evaluation, cooking loss, pH, water-holding capacity, and drip loss and ten pens with 5 pigs per replicate pen (n = 50) per treatment for carcass weight and carcass backfat thickness; SEM – standard error of the mean; [ab] means with different superscripts in the same row are significantly different at $P < 0.05$