Plant-derived polyphenols can rescue meat quality of broilers under heat stress

Bing Guo[1,3*], Nicholas James Hudson[2], Ye Lao[1], Feng Gao[3], Guanghong Zhou[3]

[1]Kemin Industries, USA;

[2]School of Agriculture and Food Science, University of Queensland, Australia.

[3]School of Food Science and Technology, Nanjing Agricultural University, China

*Corresponding author email: bing.guo@kemin.com

Abstract – This study aimed to evaluate the effect of single/combination of two plant-derived polyphenols, curcumin (CUR) and oregano essential oil (OEO) on the broilers meat quality under heat stress. 432 Arbor Acres broilers were randomly allocated into sixth dietary groups with six replicates, and 12 animals in each replicate. On day 42, we found that the overall performance of growth and meat quality in the group under heat stress were significantly reduced than control group (P<0.05), demonstrating the reliability of our heat stress model. Compared with single component, the combination of 10 ppm CUR and 10 ppm OEO could significantly reverse the negative impact of heat stress from the perspectives of antioxidant capacity and mitochondrial biogenesis-associated genes in breast muscle (P<0.05).

Key Words – Curcumin, Oregano Essential Oil, Mitochondrial

I. INTRODUCTION

Heat stress is a crucial problem in the poultry industry, which induces significantly impaired growth performance, intestinal health regeneration and poor meat quality [1]. As previously reported, heat stress can induce oxidative injury, which may lead to the increased production of reactive oxygen species (ROS) [2]. Consequently, some important meat quality traits which are significantly sensitive to the oxidative status are negatively affected, such as meat color related to ferric ion status derived from myoglobin, and drip loss/water hold capacity (WHC) associated with the protein oxidation [1]. In addition, as an important homeostasis regulator, mitochondria can also be easily affected by heat stress for both content and functionality, leading to the impaired growth performance and meat quality in livestock animals [3,4]. Therefore, in the current experiment, we compared the effect of single or the combination of CUR and OEO on broilers meat quality under simulated chronic heat stress, from the perspectives of anti-oxidative capacity and mitochondrial status.

II. MATERIALS AND METHODS

432 Arbor Acres broilers were randomly allocated into sixth dietary groups with six replicates, and 12 animals in each replicate. The simulated chronic heat stress (HS, 32 ± 1°C for 8h) was conducted from day 28 of life. The treatment details of each group are as followed: positive control (PC) which is a normal diet (ND); negative control (NC) which is a normal diet under HS; S1 diet corresponds to ND with 10 ppm CUR under HS; S2 corresponds to ND with 10 ppm OEO under HS; S3 corresponds to ND with 10 ppm CUR plus 10 ppm OEO under HS and S4 which corresponds to ND with 5ppm CUR plus 5 ppm OEO under HS. On day 42, meat quality traits were measured. We also investigated the malonaldehyde (MDA) content as antioxidative indicator, and genes like PPARG coactivator 1 alpha (*PGC1-a*), *sirtuin 1* (*SIRT1*) and uncoupling protein 1 (*UCP*1) as the reflection of mitochondrial status.

III. RESULTS AND DISCUSSION

In current research, we found that heat stress can significantly decrease the overall meat quality performance of broiler breast muscle in the present study ($P < 0.05$), in particular the PM pH and L* values at 24h PM, and drip loss at both 24h and 48h post-mortem (PM) (Table 1). Furthermore, our plant extract blend could well reverse this effect at different levels, in particular the S3 group (Table 1).

Table 1 Meat quality traits in different groups*

Item	PM time	PC	NC	S1	S2	S3	S4	SEM	P-Value
pH	24h	5.90^{a}	5.87^{ab}	6.00^{b}	5.86^{a}	$5.98a^{b}$	$5.88a^{b}$	0.016	0.10
L*	24h	48.23^{ab}	50.00^{b}	47.55^{ab}	46.81^{ab}	45.52^{ab}	48.94^{b}	0.374	0.15
Drip loss,%	24h	5.76^{a}	9.40^{b}	7.50^{ab}	7.31^{ab}	6.26^{a}	$8.06a^{b}$	0.003	0.05
	48h	9.64^{a}	13.58^{b}	13.35^{b}	10.30^{ab}	9.64^{a}	$11.8a^{b}$	0.005	0.03

*Post-mortem (PM); positive control (PC) which is a normal diet; negative control (NC) which is a normal diet under HS; S1 diet corresponds to ND with 10 ppm CUR under HS; S2 corresponds to ND with 10 ppm OEO under HS; S3 corresponds to ND with 10 ppm CUR plus 10 ppm OEO under HS and S4 which corresponds to ND with 5ppm CUR plus 5 ppm OEO under HSTo

estimate the oxidative degrees in skeletal muscle, activities of total antioxidants, catalase, glutathione peroxidase (GSH-PX) and content of MDA were measured in the breast muscle samples on day 42. However, the results showed that only MDA had significantly different expression levels in skeletal muscle among all the groups ($P < 0.05$, Table 2). Consistently, in previous research OEO was indicated to effectively decrease MDA level [5]. And given MDA is mainly generated from the lipid peroxidation process, the low MDA content is directly correlated with pleasant meat flavor and long shelf life hence the better marketability of meat cuts [6]. These results indicated that our plant extract supplementation had great potential to improve the antioxidative capacity of broilers under heat stress, thus ensuring the fundamentally physiological conditions to maintain the acceptable meat quality under heat stress.

In addition, as an important meat quality indicator, mitochondrial was regarded to be negatively affected by heat stress. In our research, we found that the genes controlling mitochondrial biogenesis and functionality were all impaired by heat stress, whilst well protected by our plant polyphenols treatment (Table 2). This is consistent with the previous report that CUR is a reliable mitochondrial biogenesis agent [7].

Table 2 MDA content and mitochondrial-related genes expression levels in different groups*

Item	PC	NC	S1	S2	S3	S4	SEM	P-Value
MDA	MDA	0.62^{b}	0.74^{c}	0.42^{a}	0.38^{a}	0.43^{a}	0.67^{bc}	0.026
PGC1-a	1.26a	0.71b	0.76b	0.65b	1.14a	0.60b	0.07	0.002
SIRT1	1.05^{a}	0.65^{b}	0.57^{b}	0.71^{b}	1.28^{a}	1.13^{a}	0.06	<0.01
UCP1	0.81^{a}	0.37^{b}	0.80^{a}	0.92^{a}	1.03^{a}	0.90^{a}	0.06	0.01

***Malonaldehyde (MDA); PPARG coactivator 1 alpha (*PGC1-a*); *sirtuin 1* (*SIRT1*); uncoupling protein 1 (*UCP*1 positive control (PC) which is a normal diet; negative control (NC) which is a normal diet under HS; S1 diet corresponds to ND with 10 ppm CUR under HS; S2 corresponds to ND with 10 ppm OEO under HS; S3 corresponds to ND with 10 ppm CUR plus 10 ppm OEO under HS and S4 which corresponds to ND with 5ppm CUR plus 5 ppm OEO under HS**

IV. CONCLUSION

In current research, a successful heat stress model of broilers was established. Two plant polyphenols, CUR and OEO were used to alleviate the negative impacts of heat stress on broilers. It was found that CUR and OEO could well exert their antioxidative feature and biological function to protect broilers against chronic heat stress, therefore they are regarded to be the promising functional ingredient candidates to rescue growth performance and meat quality of broilers under stress conditions.

ACKNOWLEDGEMENTS

The current research was fully funded by Kemin Industries.

REFERENCES

1. Estevez, M. (2015). Oxidative damage to poultry: from farm to fork. Poultry Science 94(6): 1368-1378.
2. Lin, H., Decuypere, E., & Buyse, J. (2006). Acute heat stress induces oxidative stress in broiler chickens. Comparative Biochemical Physiology Part A Molecular & Integrative Physiology 144(1):11-7.
3. Reverter, A., Okimoto, R., Sapp, R., Bottje, W. G., Hawken, R., & Hudson, N. J. (2016). Chicken muscle mitochondrial content appears coordinately regulated and is associated with performance phenotypes. Biology Open 6(1): 50-58.
4. Furukawa, K., Kikusato, M., Kamizono, T., & Toyomizu, M. (2016). Time-course changes in muscle protein degradation in heat-stressed chickens: Possible involvement of corticosterone and mitochondrial reactive oxygen species generation in induction of the ubiquitin–proteasome system. General and Comparative Endocrinology 228: 105-110.
5. Zou, Y., Wang, J., Peng, J., & Wei, H. K. (2016). Oregano Essential Oil Induces SOD1 and GSH Expression through Nrf2 Activation and Alleviates Hydrogen Peroxide-Induced Oxidative Damage in IPEC-J2 Cells. Oxidative Medicine and Cellular Longevity 288:105-10.
6. Faustman, C., Sun, Q., Mancini, R., & Suman, S. P. (2010). Myoglobin and lipid oxidation interactions: mechanistic bases and control. Meat Science 86(1): 86-94.
7. Liu, L., Zhang, W., Wang, L., Li, Y., Tan, B., Lu, X., Yu, G. (2014). Curcumin prevents cerebral ischemia reperfusion injury via increase of mitochondrial biogenesis. Neurochemical Research 39(7): 1322-1331.