



**UNIVERSITI PUTRA MALAYSIA**

***EFFECTS OF HIGH AMBIENT TEMPERATURE, CALCIUM LEVEL AND  
ZINC SOURCE ON ZINC REQUIREMENT OF BROILERS***

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ZINC SOURCE ON ZINC REQUIREMENT OF BROILERS**



**LAI PUI WAH**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,  
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**EFFECTS OF HIGH AMBIENT TEMPERATURE, CALCIUM LEVEL AND ZINC SOURCE ON ZINC REQUIREMENT OF BROILERS**

By

**LAI PUI WAH**

**April 2010**

**Chairman: Liang Juan Boo, PhD**

**Institute: Bioscience**

This study was divided into four experiments, and the primary objective was to determine the effects of Zn in broilers influenced by housing environmental temperatures, dietary Ca levels, Zn sources, acidifier and their respective interactions. In Experiment 1, the chicks were assigned to a 4 x 2 factorial arrangement with four corn-soybean meal basal diets (containing 44 mg Zn/kg) supplemented with 0, 40, 60 mg/kg Zn (Diets 1, 2 and 3, respectively; 0.8% Ca for these three diets) and non-Zn supplementation, 1.6% Ca (Diet 4), and two temperature conditions (low: 26, 24, 22°C vs. high: 30, 28, 26°C). The results showed that supplemental Zn ameliorated the adverse effect of high ambient temperature on average daily feed intake (ADFI), average daily gain (ADG) and tail feather defect score of broilers. Excess Ca disrupted Zn metabolism to exert a detrimental effect on growth and normal feathering and this was elucidated in the birds kept in low temperature condition. Both Zn supplementation and high dietary Ca reduced ( $p < 0.001$ ) abdominal fat accumulation. Whole carcass Zn increased linearly ( $p < 0.001$ ) with gradient dietary

Zn concentrations, and tibia Zn content ( $p < 0.05$ ) responded positively to dietary Zn fortification. In low temperature conditions, broilers had higher carcass Zn, Mg ( $p < 0.05$ ), CP ( $p < 0.01$ ) but lower energy retention ( $p < 0.001$ ). Higher ( $p < 0.01$ ) monounsaturated fatty acid content was found in breast meat and abdominal fat of broilers fed Diet 1 than those given Diet 2 and Diet 3. Zinc supplementation reduced ( $p < 0.05$ ) serum triglyceride.

In Experiment 2, effects of dietary treatments used in Experiment 1 on nutrient apparent digestibility in broilers were determined. The results indicated that increasing dietary Zn and Ca reduced the apparent digestibility of these elements. On the other hand, 60 mg/kg supplemental Zn reduced Cu, Fe ( $p < 0.001$ ), Mn, CP ( $p < 0.01$ ) and energy ( $p < 0.001$ ) digestibilities as compared with non-Zn supplemental broilers. High Ca diet suppressed the digestibility of P ( $p < 0.001$ ), Zn ( $p < 0.01$ ), Mg, Cu, Fe ( $p < 0.001$ ), Mn ( $p < 0.01$ ) and energy ( $p < 0.001$ ). These adverse effects might be related to mineral interactions in the gastrointestinal tract such as the formation of insoluble complexes or due to competition between minerals.

Experiment 3 further investigated the effects of two dietary Zn (0 vs. 40 mg/kg addition) and three Ca levels (0.8%, 1.2% and 1.6%) in broilers. Basal Zn concentration (38 mg/kg) was adequate for the growth requirement of broilers.

Moreover, optimum ADG was achieved in broilers fed 1.2% Ca whereas 1.6% Ca impaired ( $p < 0.001$ ) ADG and feed conversion ratio. As 40 mg/kg Zn supplementation was provided, 1.2% and 1.6% dietary Ca levels decreased Zn digestibility. High Ca diet (1.6%) reduced the apparent digestibility of DM, Cu, Ca ( $p < 0.001$ ), Fe, Mg ( $p < 0.01$ ), Mn ( $p < 0.05$ ), CP and energy ( $p < 0.001$ ) in broilers. The

fact that high dietary Ca reduced ( $p=0.01$ ) carcass fat accumulation via reduced energy digestibility was confirmed in the study herein. As dietary Zn increased, marked increase in Zn content was noted in tibia ( $p<0.001$ ), slight differences found in feather ( $p<0.09$ ) and liver ( $p<0.07$ ) but no changes ( $p>0.05$ ) in breast meat and bursa. Feather ( $p<0.001$ ) and tibia ( $p<0.05$ ) Ca retention were also increased as dietary Ca increased.

Two dietary factors, Zn sources and dietary acidification that might affect Zn utilization were studied in Experiment 4. The chicks were assigned to a 2 (ZnO vs. ZnMet) x 3 (0, citric acid, acid mixture inclusion) factorial arrangement. Overall, Zn source did not affect ( $p>0.05$ ) the growth in broilers. However, citric acid addition depressed ( $p<0.05$ ) the ADFI and ADG due to changes in feed palatability. When ZnO was fed, citric acid supplemental birds had higher Zn digestibility than those fed acid mixture ration. This was caused by the low citric acid composition in the acid mixture and it was not sufficient to affect Zn digestibility. Besides, the unprotected Zn in ZnO might bind with the phosphoric acid contained in the acid mixture and consequently impaired Zn digestibility. Conversely, in ZnMet supplemental birds, acid mixture inclusion improved Zn digestibility as compared with those fed citric acid. Zinc in ZnMet was protected from chelating agents in the gastrointestinal tract, and thus, the effect of citric acid on Zn digestibility was not found. Citric acid supplementation improved minerals digestibility coefficients of P ( $p<0.01$ ) and Fe ( $p<0.05$ ). Zinc retention in body tissues were not affected ( $p<0.05$ ) by ZnO or ZnMet. In the presence of citric acid supplementation, tibia Zn deposition in ZnMet fed broilers was greater than ZnO treatment broilers, indicating that Zn in ZnMet was protected from interaction with citric acid.

It was concluded that the 40 mg Zn/kg feed recommended by NRC (1994) was valid and met the growth requirements of broilers fed corn-soybean meal diet. Higher Zn requirement than NRC (1994) recommendation was necessary for broilers under environmental stress. Excessive dietary Ca suppressed growth and Zn utilization but the Zn content in most of the organs studied was preserved. No differences were found in growth, carcass yield and tissue Zn retention in broilers supplemented with ZnO or ZnMet. Zn oxide was still being used in commercial diet because of its' low cost. Although 3% citric acid depressed growth, DM, P and Fe digestibilities were improved. This study provided some information on the effects of Zn source, acidifier and interactions occurred between the unprotected sources (ZnO or citric acid) with protected sources (ZnMet or coated acid mixture) or among unprotected sources in broilers.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**KESAN-KESAN SUHU PERSEKITARAN TINGGI, TAHAP KALSIUM DAN SUMBER ZINK PADA KEPERLUAN ZINK DALAM AYAM PEDAGING**

Oleh

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**April 2010**

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Kajian ini dibahagi kepada empat eksperimen dan objektif utama adalah untuk menentukan kesan Zn dalam ayam pedaging dipengaruhi oleh suhu persekitaran reban, Ca pemakanan, sumber Zn, acidifier dan interaksi masing-masing. Dalam Eksperimen 1, anak ayam diperuntukkan kepada susunan berfaktor 4 x 2 dengan empat jagung kacang soya diet (mengandungi 44 mg Zn/kg) ditambah dengan 0, 40, 60 mg/kg Zn (Diet 1, 2 dan 3; 0.8% Ca untuk tiga diet ini) dan tanpa penambahan Zn, 1.6% Ca (Diet 4) serta dua keadaan suhu (rendah: 26, 24, 22°C vs. tinggi: 30, 28, 26°C). Keputusan menunjukkan bahawa penambahan Zn memperbaiki kesan buruk suhu persekitaran pada purata pengambilan makanan harian (ADFI), purata penambahan berat harian (ADG) dan kecacatan bulu ekor ayam. Lebihan Ca mengganggu metabolisme Zn dan menunjukkan kesan buruk pada pertumbuhan badan serta pertumbuhan bulu dan kesan ini jelas dalam ayam dalam keadaan suhu rendah. Kedua-dua penambahan Zn dan Ca mengurangkan ( $p < 0.001$ ) pengumpulan lemak abdomen. Karkas Zn meningkat secara linear ( $p < 0.001$ ) dengan kecerunan

kandungan Zn dalam diet, dan kandungan Zn dalam tibia ( $p < 0.05$ ) bertindak secara positif kepada penambahan Zn. Dalam keadaan suhu rendah, kandungan karkas Zn, Mg ( $p < 0.05$ ), CP ( $p < 0.01$ ) adalah lebih tinggi, tetapi penyimpanan tenaga adalah lebih rendah ( $p < 0.001$ ). Kandungan asid lemak monounsaturated yang lebih tinggi ( $p < 0.01$ ) didapati dalam daging dada serta lemak abdomen ayam pedaging diberi makanan Diet 1 berbanding dengan Diet 2 dan Diet 3. Penambahan Zn mengurangkan ( $p < 0.05$ ) serum trigliserida.

Dalam Eksperimen 2, kesan diet yang digunakan dalam Eksperimen 1 pada pencernaan apparent zat makanan dalam ayam pedaging ditentukan. Keputusan menunjukkan penambahan Zn dan Ca dalam diet mengurangkan pencernaan apparent unsur ini. Sebaliknya, 60 mg/kg penambahan Zn mengurangkan pencernaan Cu, Fe ( $p < 0.001$ ), Mn, CP ( $p < 0.01$ ) dan tenaga ( $p < 0.001$ ) berbanding dengan ayam tanpa penambahan Zn. Diet Ca yang tinggi mengurangkan pencernaan P ( $p < 0.001$ ), Zn ( $p < 0.01$ ), Mg, Cu, Fe ( $p < 0.001$ ), Mn ( $p < 0.01$ ) dan tenaga ( $p < 0.001$ ). Kesan buruk ini mungkin berhubung dengan interaksi mineral dalam saluran pencernaan seperti pembentukan kompleks tak larut atau disebabkan oleh pertandingan antara mineral.

Eksperimen 3 menyiasat kesan dua tahap Zn (0 vs. 40 mg/kg penambahan) dan tiga tahap Ca (0.8%, 1.2% dan 1.6%) dalam ayam pedaging. Kandungan Zn dalam diet asal (38 mg/kg) adalah mencukupi untuk keperluan pertumbuhan ayam pedaging. Tambahan pula, optimum ADG telah dicapai dalam ayam diberi 1.2% Ca diet manakala 1.6% Ca mengurangkan ( $p < 0.001$ ) ADG dan nisbah penukaran makanan. Apabila 40 mg/kg Zn ditambah, 1.2% dan 1.6% Ca mengurangkan pencernaan Zn.



Diet Ca yang tinggi (1.6%) mengurangkan pencernaan DM, Cu, Ca ( $p < 0.001$ ), Fe, Mg ( $p < 0.01$ ), Mn ( $p < 0.05$ ), CP dan tenaga ( $p < 0.001$ ) dalam ayam pedaging. Fakta menunjukkan Ca yang tinggi mengurangkan ( $p = 0.01$ ) pengumpulan lemak dalam karkas melalui pengurangan pencernaan tenaga disahkan dalam kajian ini. Apabila pemakanan Zn bertambah, peningkatan ketara dalam kandungan Zn diperoleh dalam tibia ( $p < 0.001$ ), perbezaan kecil didapati dalam bulu ( $p < 0.09$ ) dan hati ( $p < 0.07$ ) tetapi tiada perubahan ( $p > 0.05$ ) dalam daging dada dan bursa. Kandungan Ca dalam bulu ( $p < 0.001$ ) dan tibia ( $p < 0.05$ ) Ca bertambah apabila Ca pemakanan bertambah.

Dua faktor diet, sumber Zn dan pengasidan pemakanan yang mungkin akan menjejaskan penggunaan Zn dikaji dalam Eksperimen 4. Anak ayam diperuntukkan kepada 2 (ZnO vs. ZnMet) x 3 (0, asid sitrik, campuran asid) susunan berfaktor. Secara keseluruhannya, sumber Zn tidak menjejaskan ( $p > 0.05$ ) tumbesaran ayam pedaging. Justeru itu, penambahan asid sitrik mengurangkan ( $p < 0.05$ ) ADFI dan ADG kerana perubahan dalam rasa diet. Apabila ZnO diberi, ayam penambahan asid sitrik mempunyai pencernaan Zn yang lebih tinggi daripada ayam diberi asid campuran. Ini adalah disebabkan oleh paras asid sitrik yang rendah dalam kandungan asid campuran dan ia tidak mencukupi untuk memberi kesan kepada pencernaan Zn. Selain itu, Zn yang tidak terlindung dalam ZnO mungkin terikat dengan asid fosforik yang terkandung dalam campuran asid dan dengan itu mengurangkan pencernaan Zn.

Sebaliknya, dalam ayam yang diberi penambahan ZnMet, pencernaan Zn adalah lebih baik daripada ayam diberi asid sitrik. Zink dalam ZnMet dilindungi daripada ejen pengkelatan dalam saluran pencernaan, dan oleh itu, kesan asid sitrik pada pencernaan Zn tidak didapati. Penambahan asid sitrik meningkatkan pencernaan mineral P ( $p < 0.01$ ) dan Fe ( $p < 0.05$ ). Pengekalan Zn dalam tisu badan tidak dijejas

( $p > 0.05$ ) oleh ZnO atau ZnMet. Dalam kehadiran penambahan asid sitrik, ayam diberi ZnMet mempunyai kandungan Zn dalam tibia lebih tinggi daripada ayam diberi ZnO, menunjukkan bahawa Zn dalam ZnMet terlindung daripada interaksi dengan asid sitrik.

Adalah disimpulkan bahawa 40 mg Zn/kg diet yang dicadangkan oleh NRC (1994) adalah sah dan memenuhi syarat pertumbuhan ayam pedaging yang diberi diet jagung kacang soya. Keperluan Zn yang lebih tinggi daripada cadangan NRC (1994) adalah perlu untuk ayam pedaging di bawah tekanan persekitaran. Pemakanan Ca yang tinggi mengurangkan tumbesaran dan penggunaan Zn tetapi kandungan Zn dalam kebanyakan organ dikaji dipelihara. Tiada perbezaan ditemui dalam tumbesaran, hasil karkas dan tisu pengekal Zn dalam ayam pedaging diberi penambahan ZnO atau ZnMet. Zink oksida tetap digunakan dalam diet komersil disebabkan oleh kosnya yang rendah. Walaupun 3% asid sitrik mengurangkan pertumbuhan, pencernaan DM, P dan Fe bertambah baik. Kajian ini menyediakan maklumat tentang kesan sumber Zn, acidifier dan interaksi berlaku antara sumber tidak terlindungi (ZnO atau asid sitrik) dengan sumber terlindung (ZnMet atau campuran berasid) atau antara sumber-sumber tidak terlindung dalam ayam pedaging.

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I certify that an Examination Committee met on **9 April 2010** to conduct the final examination of **Lai Pui Wah** on her **PhD** thesis entitled “Effects of High Ambient Temperature, Calcium Level and Zinc Source on Zinc Requirement of Broilers” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded Doctor of Philosophy.

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## DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Putra Malaysia or other institutions.



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**LAI PUI WAH**

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