Growth performance and Newcastle disease antibody titres of broiler chickens fed palm-based diets and their response to heat stress during fasting

Einfluss von Hitzestress auf die Wachstumsleistung und Newcastle Disease Antikörpertiter von Broilern während einer Nüchterungsperiode bei Fütterung Palmkernmehlhaltiger Rationen

I. Zulkifli, J. Ginsos, P. K. Liew and J. Gilbert


Introduction

Malaysia is one of the world largest producers of palm oil, a major edible vegetable oil. Palm kernel meal (PKM) is the major by-product of palm kernel oil extraction. Studies as early as 1924 suggested that PKM is a potential source of energy and protein for livestock (Alimon and Hair-Bejo, 1995). However, the use of PKM for monogastric animals is limited by its high fibre content (146.1 g/kg) and dry gritty texture that reduce feed palatability. Nevertheless, there is considerable interest in utilizing PKM as it provides a cheaper and readily available poultry feed ingredient. Broiler chickens can utilize PKM at the inclusion level of 200 g/kg without any detrimental effects on growth and feed efficiency (Yeong and Mukherjee, 1983; Ngopayou, 1984).

It is recommended to limit the use of fibrous ingredients in poultry diets under heat stress conditions (Leeson and Summers, 1997) to reduce heat of crude fibre digestion (Chong, 1999). High fibre diets may also reduce availability of essential amino acids in heat-stressed chickens and thus their performance (Koelkebeck et al., 1998). Therefore, the feeding of PKM to broiler chickens under high ambient temperatures is of concern. The addition of PKM into poultry diets inevitably results in the need for greater inclusion of oil to offset the replacement of maize.

It is well documented that a higher dietary fat content contributes to improved heat tolerance in broiler chickens (Dagher, 1995). The effect of diets containing PKM and high levels of palm oil on heat tolerance in poultry has not been studied previously. Knowledge of the possible relationship between dietary PKM, palm oil, and heat stress would be of value to broiler growers in developing nations who are constantly searching for unconventional agricultural by-products as alternative ingredients in poultry diets.

Various management practices can be adopted to alleviate the consequences of high ambient temperatures. However, most management options involve high cost and may not be economical. A possible strategy to offset the adverse effects of heat stress is short-term fasting. Fasting intervals as short as 3 h prior to heat exposure enhanced survivability of heat-stressed broilers, while withdrawing feed after the onset of heat stress was of little value (Tenter et al., 1987). This study evaluated the effects of feeding diets containing PKM and high levels of palm oil, and short-term fasting on performance, body temperature and Newcastle disease (ND) antibody in broiler chickens subjected to heat stress.

Materials and Methods

Experimental design and birds

One hundred ninety two day-old male broiler chicks (Cobb strain) were distributed at random to 32 cages in three-tiered batteries with wire floors (6 birds per cage). The chicks were raised in an environmentally controlled house. Ambient temperature on day (d) 1 was set at 32 ± 1 °C and then gradually reduced until 24 ± 1 °C by d 21. Live Newcastle disease (ND) vaccine (Nobilis ND Clone 30, Intervet International, the Netherlands) was administered intraocularly on d 7 and d 21. Birds received continuous lighting and had free access to water.

A 2 × 4 factorial design was established to include 2 levels of dietary PKM (0 g/kg and 200 g/kg) and 4 fasting periods (10 h, 7 h, 4 h and, 0 h) with 4 experimental units per diet-fasting duration subgroup.

Diets, feeding and fasting duration

From d 1, the chicks were fed diets containing either 0 g/kg (control) or 200 g/kg PKM. Solvent-extracted PKM was obtained from a local solvent extraction plant in Selangor, Malaysia. The nutrient composition of the PKM is shown in Table 1. The diets (Table 2) were formulated to

<table>
<thead>
<tr>
<th>Table 1. Chemical composition of palm kernel meal [g/kg]</th>
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<tr>
<td>Dry matter</td>
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<tr>
<td>Crude protein</td>
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<tr>
<td>Crude fibre</td>
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<tr>
<td>Ether extract</td>
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<tr>
<td>Ash</td>
</tr>
<tr>
<td>Gross energy [MJ/kg]</td>
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</tbody>
</table>
be isoenergetic and isonitrogenous, and to meet nutrient requirements (NRC, 1984) for the starter (d 1 to d 21) and grower (d 22 to d 42) periods. Because of the low available metabolizable energy (ME) value of PKM, inclusion of high levels of palm oil in the starter (104.4 g/kg) and finisher (91.1 g/kg) diets was necessary to offset the replacement of maize.

Heat stress challenge

Commencing from d 35 (week 6), all the chicks were subjected to 4-h episodes (from 13.30 h to 17.30 h) of heat stress daily. The assigned duration and timing of the heat stress challenge was based on the natural climatic conditions in Malaysia. During the heat stress period, chicks were subjected to 1 of 4 fasting durations of 10 h (7.30 h to 17.30 h) (10 h FAST), 7 h (10.30 h to 17.30 h) (7 h FAST), 4 h (13.30 h to 17.30 h) (4 h FAST), and 0 h (ad libitum feeding as controls) (0 h FAST).

Chicks were individually weighed, and food intake and food efficiency (gain/food) were determined for each cage on a weekly basis. Mortality was recorded on a cage basis. Cloacal temperatures were measured from 10 randomly selected birds per diet-fasting subgroup at 0700 h and 1730 h on d 35, 38 and 41 using an electronic thermometer. The probe was inserted about 3 cm into the cloaca for about 30 s.

ND antibody measurement

Antibody response to live ND vaccine was used to evaluate the humoral immunity of the birds. Blood samples (0.5 ml) from all the birds were withdrawn from the wing vein prior to and during heat stress on d 35, 38, 41 of the experiment and processed serum samples stored at −20 °C until analysis. Antibody titres to ND vaccine were measured by ELISA using commercial kits (IDEXX Laboratories, U.S.A.) and procedures recommended by the manufacturer.

Data analysis

Antibody titres were transformed to natural logarithms before statistical analyses. The body weight, food intake and food efficiency from prior to heat stress period (d 1 to 35) were tested for the main effect of diet. Data collected during the heat stress period were analysed with the main effects of fasting duration, diet and their interactions in a factorial arrangement. The antibody titres and rectal temperatures were subjected to repeated measures analysis of variance. General Linear Models procedure of SAS® (SAS INSTITUTE, 1990) were used. Significance of differences among treatment means was tested with Duncan’s multiple range test. The mortality data were subjected to chi-square analysis because they were not normally distributed (Steel and Torrie, 1960). Statistical differences were based on P ≤ 0.05.

Results

Body weight, food intake, and food efficiency data are presented in Table 3. Prior to heat stress exposure (d 1–35), diet had no effect on body weight gain. However, from d 1 to d 35, birds fed 200 g/kg PKM-based diet consumed more food and had poorer food efficiency than those provided with the control diet. There was no signifi-

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Table 2. Composition of the basal diets

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Starter (d1 to d 21)</th>
<th>Grower (d 22 to d 42)</th>
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<tbody>
<tr>
<td></td>
<td>Control</td>
<td>PKM-based</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>PKM-based</td>
</tr>
<tr>
<td>Ground yellow maize</td>
<td>538.9</td>
<td>292.8</td>
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<tr>
<td>Soybean meal</td>
<td>361.9</td>
<td>341.8</td>
</tr>
<tr>
<td>Fishmeal</td>
<td>30.0</td>
<td>30.0</td>
</tr>
<tr>
<td>Palm kernel meal 1</td>
<td>0.0</td>
<td>200.0</td>
</tr>
<tr>
<td>Palm oil</td>
<td>37.3</td>
<td>104.4</td>
</tr>
<tr>
<td>60% Choline chloride</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Trace element and vitamin mix 2</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Salt</td>
<td>2.0</td>
<td>2.1</td>
</tr>
<tr>
<td>Antioxidant (santoquin)</td>
<td>0.125</td>
<td>0.200</td>
</tr>
<tr>
<td>DL-methionine</td>
<td>1.756</td>
<td>1.900</td>
</tr>
<tr>
<td>Limestone</td>
<td>13.0</td>
<td>11.8</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>11.5</td>
<td>11.50</td>
</tr>
<tr>
<td>Total</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>Calculated composition (g/kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude protein</td>
<td>220</td>
<td>223</td>
</tr>
<tr>
<td>Crude fat</td>
<td>63.1</td>
<td>127.0</td>
</tr>
<tr>
<td>Crude fibre</td>
<td>38.0</td>
<td>57.6</td>
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<tr>
<td>Calcium</td>
<td>10.2</td>
<td>10.3</td>
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<tr>
<td>Phosphorous</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Metabolisable energy (MJ/kg)</td>
<td>13.1</td>
<td>13.1</td>
</tr>
</tbody>
</table>

1 Metabolisable energy of PKM: 6.65 MJ/kg (CHONG, 1999)
2 supplied per kg diet: Fe, 100 mg; Zn, 100 mg; Mn, 110 mg; Cu, 20 mg; I, 2 mg; Ca, 0.6 mg; Se, 0.2 mg; antioxidant (santoquin), 0.6 mg; folic acid, 0.33 mg; thiamin, 0.83 mg; pyridoxine, 1.33 mg; biotin 2%, 0.03 mg; riboflavin, 2 mg; phylloquinone, 1.33 mg; cyanocobalamin, 0.03 mg; pantothenate, 3.75 mg; niacin, 23.3 mg; retinol, 2 mg; cholecalciferol, 0.025 mg; dl-a-tocopherol, 23 mg
cant diet × fasting period interaction effect on body weight, food intake and food efficiency during the heat stress (d 35 to 41). Neither did diet nor fasting duration alone significantly affect body weight and food intake. While diet had no effect on food efficiency during the heat stress period, the 10 h FAST birds had the best food efficiency compared to their 4 h FAST and 0 h FAST counterparts. The food efficiencies of birds subjected to 10 h FAST and 7 h FAST were similar.

Diet had no significant effect on mortality rate prior to heat stress treatment (Table 4). The mortality percentage of the birds fed control (1.0%) and PKM-based (3.1%) diets during the period of d 1–35 can be considered as acceptable under the Malaysian feeding and management conditions. Post-mortem examination did not suggest any infectious diseases. Mortality rate during the heat exposure was significantly higher in birds on the control diet than those fed the PKM-based diet. The heat stress challenge...
resulted in a high mortality among the 0 h FAST and 4 h FAST birds but not among those subjected to 7 h FAST and 10 h FAST.

Neither stage of heat challenge nor diet had significant effect on body temperature of broilers at 07.00 h (Table 5). The mean body temperatures of the 7 h FAST and 10 h FAST birds were lower than their 0 h FAST and 4 h FAST counterparts at 07.00 h. The recorded body temperature at 17.30 h was significantly affected by stage of heat treatment, diet and fasting interval. Following 4 (d 38) and 7 (d 41) days of heat exposure, the body temperatures of birds recorded were higher (P < 0.05) than those measured on the first day (d 35) of heat challenge. The recorded body temperature was lower (P < 0.05) in the birds fed the PKM-based diet compared to those on the control diet. The 4 h FAST and 0 h FAST chicks had higher body temperatures than their 10 h FAST counterparts in response to the heat challenge. The mean body temperatures of 7 h FAST birds did not differ from the other three groups.

A significant diet × stage of heat challenge interaction was noted for the antibody values (Table 6). Although the control birds had higher antibody titres than those fed PKM-based diets prior to heat stress treatment, both groups of birds had similar antibody response following heat exposure. The antibody titres of birds fed diet containing 200 g/kg PKM remained constant throughout the 7-d period of heat treatment. On the contrary, there was a large (P < 0.05) decline in ND antibody titre of chicks fed control diet during the heat exposure. Antibody response to ND vaccine was not influenced by fasting interval (0 h FAST, 2738 ± 429; 4 h FAST, 3647 ± 458; 7 h FAST, 2791 ± 199; 10 h FAST, 3273 ± 342).

Discussion

The present study confirmed the findings of Yeong and Mukherjee (1983) and Ndongapayou (1984) that 200 g/kg PKM-based diet had no detrimental effect on the body weight of broiler chickens. Conversely, Ahmad (1982) reported that weight gain of broilers were significantly reduced when fed diets containing more than 100 g/kg PKM. These contradictions could be attributed to the extent of oil extraction from palm kernel and also to the methods of processing used in producing PKM (Onwudike, 1986).

The higher food consumption of the birds on the PKM-based diets, as compared to those provided the control diets, could be attributed to the improved palatability of the former as a result of high inclusion of palm oil. It is well documented that addition of fat stimulates feed and ME energy consumption in poultry (Daghiri, 1995). The positive relationship between food consumption and fibre content in poultry has been documented (Savory and Gentle, 1976a, b; Summers and Leeson, 1986). Despite providing various diets with similar ME content, Onifade and Babatunde (1998) noted that addition of brewers’ dried grains increased food intake and the authors attributed the findings to high fibrous nature of the ingredient. In the present study, the extra-intake of PKM supplemented feed did not produce a corresponding increase in body tissues and thus, resulted in a poorer food efficiency. According to Onifade and Babatunde (1998), fibrous diets increased the rate of food passage in the gastrointestinal tract and hence, reduced nutrient utilization.

Palm kernel meal, a fibrous ingredient, may exacerbate heat-stress related problems in broilers because of the extra heat produced during the digestion and fermentation of crude fibre. However, the effect of diets containing PKM and high fat on broiler chickens under high ambient temperatures is unknown. The data presented here show that feeding PKM-based diets with high dietary fat can alleviate, at least in part, the detrimental consequences of high ambient temperatures in broilers. Although imposing a 7-d period of heat challenge resulted in hyperthermia in both groups of birds, the increase in body temperature in the chicks fed the PKM-based diet was lower than their control counterparts. Elevated body temperature as a response to heat exposure in chickens has been reported (Cooper and Washburn, 1998; Zulkifli et al., 1999). The close relationship between body temperature and survivability under heat stress conditions was clearly reflected in the present study by a marked difference in mortality rate between birds fed the diets containing 0 g/kg and 200 g/kg PKM. Feeding diets containing 200 g/kg PKM can decrease mortality resulting from the heat treatment by as much as 75% (17.2% vs. 4.3%).

Thus, the present findings strongly suggest that the high addition of palm oil (starter diet, 37.3 g/kg versus 1047.4 g/kg; grower diet, 24.4 g/kg versus 91.1 g/kg) may offset the adverse effects of PKM, a high fibrous ingredient, on heat stressed broiler chickens. Dietary fat has been demonstrated to be beneficial to both broilers and layers under heat stress conditions (Dale and Fuller, 1979; Daghiri, 1987). It is generally recommended to provide as much of the required energy from fats rather than protein and cereal grains since fat has a lower heat increment than either protein or carbohydrates (Austin, 1985). According to Mateos and Sell (1981), dietary fat may also increase the energy value of the other food constituents.

Further, two more factors also suggest that there was an increased susceptibility of birds on the control diet to heat stress-related problems. Prior to the heat exposure, although the birds fed the control diet had greater antibody response against ND vaccine and food efficiency ratios than those on PKM-based diet. This improvement was not extended into the period of heat treatment. The retardation of immune response and food efficiency attributed to high ambient temperatures is well documented (Thaxter, 1978; Daghiri, 1995), it appears that the adverse effects of the heat challenge was more severe in chicks fed the control diet.

Dietary fats have been recognised as important modulators of the immune system (Johnston, 1985; 1988). The
amount and type of fat in the diet may influence both cell mediated and humoral immunity. Studies by Fritsche et al. (1991) suggested that oils rich in omega-3 fatty acids enhanced antibody production and lymphocyte proliferation in chickens. In the present study, prior to heat challenge (d 35), birds provided diets containing PKM and high levels of palm oil had lower antibody response against ND vaccine than those fed control diet. Thus, it appears that high levels of dietary palm oil, a highly saturated fat source (LeeSon and Summer, 1997), may suppress the humoral immunity of broilers raised under ambient temperatures of 24 ± 1 °C.

The present study provides further confirmation that short term fasting may reduce increases in body temperature and mortality, and improve food efficiency during exposure to high ambient temperatures (Francis et al., 1991; Teeter et al., 1987; Zulkifli and Fauzzi, 1996). Reduction in dietary thermogenesis (Kohne et al., 1973), metabolic shift from carbohydrate to fat catabolism (McCormick et al., 1979), and alteration in blood acid-base and electrolyte balances (Ait-Boulaïsen et al., 1989) may in part account for the phenomenon. Menc (1992) indicated that fasting elicited both metabolic and behavioural responses. The results of previous experiments indicated that feed restricted broilers rested more than those fed ad libitum (Zulkifli and Fauzzi, 1996). The capacity for heat loss can be altered by reduction in activity (Squibb and Wogan, 1960), so behavioural responses during the heat challenge may have also contributed to the lower body temperature and mortality rate of the fasted chicks.

For fasting to be effective in alleviating the detrimental effects of heat stress, it is imperative that the onset of fasting is in synchrony with heat exposure (Daghri, 1995). The lack of effect of 4 h fast (from 1330 h to 1730 h) (i.e. 0 h prior heat exposure) on the survivability of the heat-stressed birds revealed a discrepancy between our findings and those of Teeter et al. (1987). Teeter et al. (1987) noted that 7-week old broilers food restricted 0, 3 and 6 h prior to onset of heat challenge had similar mortality rates when exposed to high ambient temperatures. There is no clear explanation for this difference in effect, but it may be associated with discrepancies in age of the birds during heat challenge and the heat treatment regimen.

It can be concluded that, under the conditions of the present experiment, providing diets containing 200 g/kg PKM and high levels of palm oil may enhance the ability of broiler chickens to withstand high ambient temperatures. The present results in combination with earlier literature (Teeter et al., 1987; Zulkifli and Fauzzi, 1996) demonstrated the practical value of short-term fasting in reducing mortality of heat-stressed broiler chickens.

### Summary

An experiment was conducted to determine the response of male broiler chickens to diets containing either 0 g/kg (control) or 200 g/kg palm kernel meal (PKM), and to heat stress when fasted for various periods (10 h, 7 h, 4 h and 0 h) and fed same diets from 35 to 41 days of age. The PKM-based diets were added with high levels of palm oil in replacement for maize. Prior to heat stress, broilers fed the PKM-based diet consumed more food and had poorer food efficiency than those on the control diet. During the 7-d of heat stress, birds fasted for 10 h had the best (P < 0.05) food efficiency but diet had no effect on growth performance. Provision of the PKM-based diet, and food restriction for 10 h and 7 h gave smaller increases in body temperature and mortality in response to the heat stress. While the Newcastle disease antibody titre of the birds fed the PKM-based diet remained constant throughout the 7-d period of heat stress, there was a big (P < 0.05) decline in antibody titres of chicks fed the control diet. Antibody response was not affected by fasting interval.

### Keywords

Broiler chickens, palm kernel meal, heat stress, fasting

### Zusammenfassung

Einfluss von Hitzestress auf die Wachstumsleistung und Newcastle Disease Antikörperter von Broilern während einer Nüchternungsperiode bei Fütterung Palmkernehlhaltiger Rationen

Das Ziel der vorliegenden Untersuchung war, die Reaktion von männlichen Broilern auf Hitzestress während verschiedener Nüchternungsphasen (10 h, 7 h, 4 h, 0 h) zwischen dem 35. und 41. Lebensstag zu untersuchen, wenn entweder eine Kontrollration oder eine Ration mit 200 g/kg Palmkernehl (PKM) verfüttert wurde. Der PKM-Ration wurden zusätzlich hohen Mengen an Palmöl zugesetzt, im Austausch von Mais. Vor der Hitzbelastung verzehrten die Broiler, die mit der PKM-Ration gefüttert wurden, mehr Futter und wiesen eine ungünstigere Futtermittelverwertung auf als die Tiere der Kontrollgruppe. Während der siebenständigen Hitzestressphase zeigten die Tiere, die für 10 Stunden genässt wurden, die günstigste Futtermittelverwertung (P < 0.05), während die Futtermittelrationen keinen Einfluss auf die Wachstumsleistung hatten. Der Ein satz der PKM-Ration und der Futterentzug für 10, 7, 4 h führten zu geringeren Zunahmen der Körpertemperatur und der Mortalität unter Hitzestress. Während die Newcastle Disease Antikörperter bei Fütterung der PKM-Ration während der siebenständigen Hitzestressphase unverändert blieben, gingen die Antikörperter bei der Kontrollgruppe deutlich zurück (P < 0.05). Die Antikörperreaktion wurde nicht durch die Nüchternungsphase beeinflusst.

### Stichworte

Broiler, Fütterung, Palmkernehl, Hitzestress, Nüchternung

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Correspondence: Dr. I. Zulkifli, Department of Animal Science, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia. E-mail: zulkifli@agri.upm.edu.my