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Physico-chemical and compositional changes in proprietary finished feeds stored under different conditions

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SUMMARY

Storage of feed plays an important role in the economic and health aspect of livestock production. This study was conducted to investigate the effects of varying storage conditions (lit and dark room) on physical changes, occurrence of insects in stored feed, storage loss and nutrient composition of propietary selected broiler finisher feeds. Bags of 25 kg each of broiler finisher diets from four feed companies (A, B, C and D) were obtained on the day of production and were stored under two storage media (lit and dark room) for a period of 8 weeks. The experiment was arranged in a 4 x 2 factorial layout to form eight treatments with 5 replications. Feed colour, storage loss, occurrence of insects, and proximate analysis were carried out at 2 week intervals. Data generated were statistically analyzed by ANOVA technique in a 4 x 2 factorial design using PROC GLM procedure of SAS (2007). Storage temperature (27.27 °C and 26.65 °C for lit and dark room, respectively) and relative humidity (79.83% and 80.64% for lit and dark room, respectively) monitored were not significantly ($p>0.05$) different. Colour changes were observed in the feed from the 29th day of storage. By the 42nd day, presence of lesser grain borer (*Rhyzopertha dominica* F.) was observed in all the feeds. Appearance of frass, dusty particles and webbing were observed in feeds stored in lit room on 42nd day and those in dark room on 56th day. Storage loss (%) was reduced ($p<0.05$) by 28.10% in feeds stored in dark room compared to the lit room. Interactive effect of feed brands x storage conditions showed that feed C stored in dark room had relatively lower ($p<0.05$) weight loss. Nutrient profile of the feeds was influenced ($p<0.05$) by feed brands and length of storage. Feeds stored in dark room had higher crude fat and ashes at 42nd day as well as crude fat at 56th day. It was recommended that finished feeds should be stored with minimal exposure to light, so as to maintain their nutrient quality.

ADDITIONAL KEYWORDS

Finished feeds.
Nutritive value.
Storage conditions.
Finisher diets.
Broiler chickens.

Cambios físico-químicos y de composición en los piensos comerciales de finalización almacenados en diferentes condiciones

RESUMEN

El almacenamiento de piensos desempeña un papel importante en el aspecto económico y sanitario de la producción pecuaria. Este estudio se llevó a cabo para investigar los efectos de diferentes condiciones de almacenamiento (luz y espacio oscuro) sobre los cambios físicos, la presencia de insectos en el alimento almacenado, la pérdida por almacenamiento y la composición de nutrientes de piensos comerciales de terminación para pollos de engorde. En el día de la producción se obtuvieron, sacos de 25 kg de pienso de acabado para pollos de engorde producidos en cuatro empresas de alimentación (A, B, C y D) y se almacenaron en dos condiciones de almacenamiento (iluminación y oscuridad) durante un período de 8 semanas. El experimento se dispuso en un esquema factorial 4 x 2 para formar ocho tratamientos con 5 repeticiones. Al cabo de dos semanas se analizaron el color del pienso, la pérdida de almacenamiento, la aparición de insectos y el análisis inmediato. Los datos generados se analizaron estadísticamente mediante la técnica ANOVA en un diseño factorial 4 x 2 utilizando el procedimiento PROC GLM de SAS (2007). La temperatura de almacenamiento (27,27 °C y 26,65 °C para las habitaciones iluminada y oscura, respectivamente) y la humedad relativa (79,83 % y 80,64 % respectivamente) no fueron significativamente diferentes ($p>0,05$). Se observaron cambios de color en el pienso a partir del 29º día de almacenamiento. A los 42 días, se observó presencia de barrenador menor del grano (*Rhyzopertha dominica* F.) en todos los piensos. Se observó la aparición de residuos, partículas polvorientas y estructuras en los alimentos almacenados en iluminación el día 42 y en oscuridad el día 56. La pérdida de almacenamiento (%) se redujo ($p<0,05$) en un 28,10 % en los alimentos almacenados en oscuridad en comparación con la iluminación. El efecto interactivo de las marcas de alimentación x condiciones de almacenamiento, mostró que el alimento C almacenado en la habitación oscura tenía una pérdida de peso relativamente menor ($p<0,05$). El perfil nutricional de los piensos fue influenciado ($p<0,05$) por las marcas de alimento y la duración del almacena-

PALABRAS CLAVE ADICIONALES

Alimentos terminados.
Valor nutritivo.
Condiciones de almacenaje.
Dietas de acabado.
Pollos de engorde.

INFORMATION

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miento. Los alimentos almacenados en la habitación oscura tenían más grasa bruta y cenizas a los 42 días, y más grasa bruta a los 56 días. Se recomienda que los piensos comerciales se almacenen con mínima exposición a la luz, de manera que se mantenga la calidad de los nutrientes.

INTRODUCTION

The success of poultry farming enterprise is hinged primarily on the quality of diets offered on the farm. Inadequate technical know-how on least-cost ration formulation compels many farmers to depend solely on proprietary finished feeds. Seasonal changes in feedstuffs availability and increased price might also compel feed manufacturers to substitute conventional feed resources with non-conventional ingredients in feed formulation which often results in changes in nutritive value of the finished feeds (Parish, 2011). In recent times, it has been noted that most commercial feeds failed to meet up with the nutritional requirements of birds (Kudu *et al*., 2008) because the actual nutritive value of the complete diets varied significantly from the expected diet specifications (Ru *et al*., 2003) which could result to delay in reaching market weight of broilers and other negative consequences.

Storage of feed ingredients and finished feed is inevitable both for feed manufacturers and poultry farmers. Animal feedstuffs are usually purchased during the time of abundance to ensure their availability all year round while minimizing the cost of production (Njobeh *et al*., 2004). Yegany *et al*. (2002) noted that a batch of ingredient could be handled some 10-15 times before it reaches its final destination. In the same vein, complete diets, usually produced in batches, are normally stored by the feed distributors for couple of weeks or more before being purchased by poultry farmers. Feeds that are improperly stored or preserved can be edible but may have lost much of its nutritive value or even become toxic through spoilage. Yegany *et al*. (2002) reported that nutritional value of poorly or inadequately stored feeds or feedstuffs diminishes daily. Spoilage or denaturing of feed can either be as a result of the attack of fungi, bacteria, adverse environmental condition, and rodents which are responsible for feed loss during storage. Furthermore, metabolic activity of enzymes and micro-organisms could render feeds unfit for use (chiefly as a result of mould growth) by producing metabolic heat and water. Both of which contribute to an increase in temperature and moisture content of the stored feed (Reddy, 2001).

The rate of feed value deterioration depends partly on its quality when it was received, but very largely on storage conditions. Waheed *et al*. (2004) observed that light, relative humidity and high storage temperature accelerated spoilage process. Oxidation in feedstuffs and finished feeds often results to significant reduction in nutrient profile by degrading the energy content, available amino acids and destruction of essential vitamins by free radicals and reactive oxygen species (ROS) which consequently leads to decrease in animal productivity, impaired immune function and reduced profit margin (Maciorowski *et al*., 2006). Although the use of antioxidants and preservatives can prolong the shelf-life of feeds with positive effects on broiler performance (Njobeh *et al*., 2004), their incorporation in proprietary finished feeds could not be ascertained as it could increase the cost of production. Furthermore, the critical role of feed distributors in delivering safe and high-quality feeds to the animals cannot be underestimated because storage conditions and management practices can increase uncertainty in feed nutrient composition if not managed properly. Considering the prevailing storage facilities employed at sales outlets, especially in South-west, Nigeria, this study aimed at investigating the influence of light exposure on the finished feeds prior their use on the farms. Studies in which the changes in nutritive value and storage loss of proprietary finished feeds during storage were evaluated are limited. In addition, there is paucity of information on the effect of pro-oxidative factor (light) on the nutritive value of proprietary finished feeds available for poultry farmers. Hence, this study was designed to assess the variability in feed value deterioration, storage loss, feed colour as well as absence of insects in four proprietary finished broiler feeds stored in lit and dark rooms.

MATERIALS AND METHODS

The experiment was conducted at the Animal Nutrition Laboratory of the Federal University of Agriculture, Abeokuta, Nigeria. Bags of 25 kg each of the commercial broiler finisher diets manufactured by four (4) different feed companies (A, B, C, and D) were obtained on the day of production at the feed mills and/or nearest feed depots in Abeokuta, Ogun State, Nigeria. They were divided into 10 parts (2.5 kg each) and further sub-divided into two groups of 5 parts. They were stored in bags which were placed on wooden pallets under two storage media (lit and dark rooms) for a period of 8 weeks. The experiment was arranged in a 4 x 2 factorial layout (feed brands – A, B, C, and D; storage conditions – lit room and dark room) to form 8 treatments. Each treatment had 5 replicates. The lit room is a normal daylight room which received 12 hrs light and 12 hrs darkness with no artificial light while the dark room had neither natural nor artificial light. Feeds A, B, C, and D stored in lit room were designated as AL, BL, CL and DL, respectively while those stored in dark room were designated as AD, BD, CD, and DD, respectively. All feeds, except C, are in mash form. Feed C (pellet) was included in this study because it is one of the most commonly used proprietary finished feeds across the country, and even the most preferred by some poultry farmers. Since it is usually being subjected to similar storage condition as mash diets, it therefore becomes imperative to evaluate the extent to which storage conditions affect its nutritive quality. Temperature and relative humidity of the stores were monitored with digital thermometer and hygrometer (HTC 1 brand, Yueqing Xinyang Automation Equipment Co. Ltd., China).

At the start of the experiment, and thereafter at 2 weeks intervals, feed colour was measured using Munsell® Colour Chart, storage loss (relative weight changes, expressed in %) was evaluated and the occurrence of insects were noted in stored feeds. Triplicate samples of each ration were drawn and analyzed for proximate composition (Moisture, crude protein, crude fat, ash) as described by Association of Analytical Chemists (AOAC, 2000). Data obtained were subjected to analysis of variance (ANOVA) technique in a 4 x 2 factorial design using General Linear Model procedure of SAS (2007). Duncan's Multiple Range Test ($p<0.05$) was applied to compare the significant differences between treatment means. The statistical model used was:

$$Y_{ijk} = \mu + A_i + B_j + A^*Bij + \Sigma_{ijk}$$

Y_{ijk} = Observed value / output;

A_i = Effect of ith feed brands (i = A, B, C & D);

B_j = Effect of jth storage conditions (j = lit room & dark room);

A*Bij = Interaction between ith feed brands and jth storage conditions;

Σ_{ijk} = Random error associated with each record.

RESULTS

The results of ambient temperature and relative humidity (RH) obtained during this study are shown in **figures 1 and 2**. The average values of temperature and humidity (mean ± SD) recorded in lit room (27.64 ± 1.63 ^{o}C; 79.36 ± 4.32 %) and dark room (26.73 ± 0.47^{o}C; 80.32 ± 1.05 %) in that order did not differ significantly ($p<0.05$). Regarding colour, feeds retained their original colour until after 28th day when noticeable colour changes were observed **(table I)**. Influence of storage on the occurrence of insects in stored broiler finisher diets is shown in **table II**. Incidence of insects (lesser grain borer – *Rhyzopertha dominica* F) was first noticed in BL at 2nd week followed by CL and AD at 4th week. By the 6th week, presence of insects (adult and larvae) was observed in all the feeds. Appearance of frass, dusty particles and webbing were observed in feeds stored in lit and dark rooms beginning from the 6th and 8th week, respectively.

Storage loss (%) was influenced ($p<0.05$) by main and interactive effects of feed brands and storage conditions **(table IV)**. Significant reduction in weight of stored feeds as influenced by feed brands commenced after 2nd week with highest ($p<0.05$) total loss recorded in feeds A and D. Storage loss (%) was reduced ($p<0.05$) by 28.10% in feeds stored in dark room. The feed brands x storage conditions interaction showed that feed C stored in dark room had relatively lower ($p<0.05$) weight loss (2.43%) which is about 68.85% reduction when compared with values obtained for feed D stored in lit room.

The effects of feed brands and storage conditions on the nutrient composition of broiler finisher feeds investigated are presented in **table V**. Nutrient content varied significantly ($p<0.05$) among feed brands. Moreover, duration of storage altered ($p<0.05$) the nutrient profile of the feeds. Unlike storage conditions, variation in feed brands produced significant ($p<0.05$) effects on their nutritive value at 2nd and 4th week. Feed stored in dark room had higher ($p<0.05$) crude fat (8.15 %) and ash (17.84 %) at 6th week as well as crude fat (8.13 %) at 8th week. MC and Ash values increased while crude fat and CP decreased with time, except for CP at 6th week.

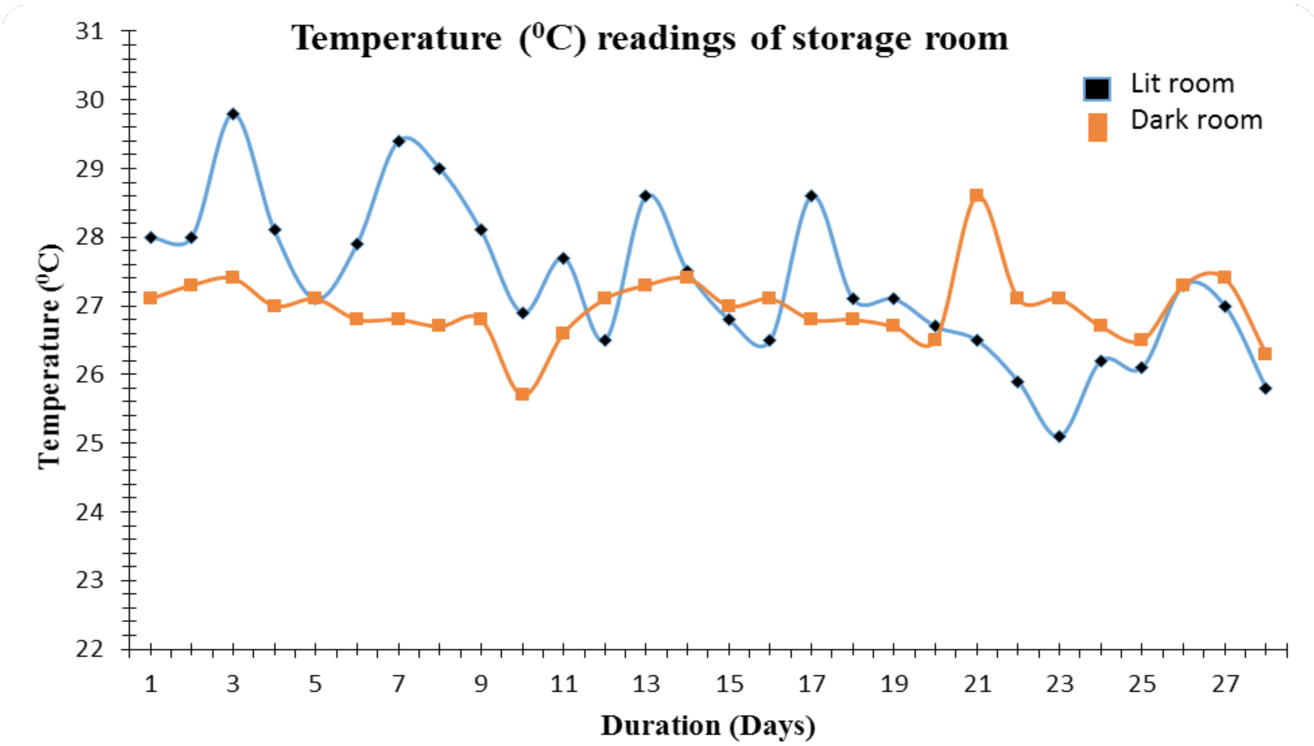

Figure 1. Evolution of temperature (ºC) of the stores (lit vs dark room) against duration of storage (Evolución de la temperatura (ºC) de los locales de almacenamiento (iluminación vs oscuridad) en función de la duración del almacenamiento).

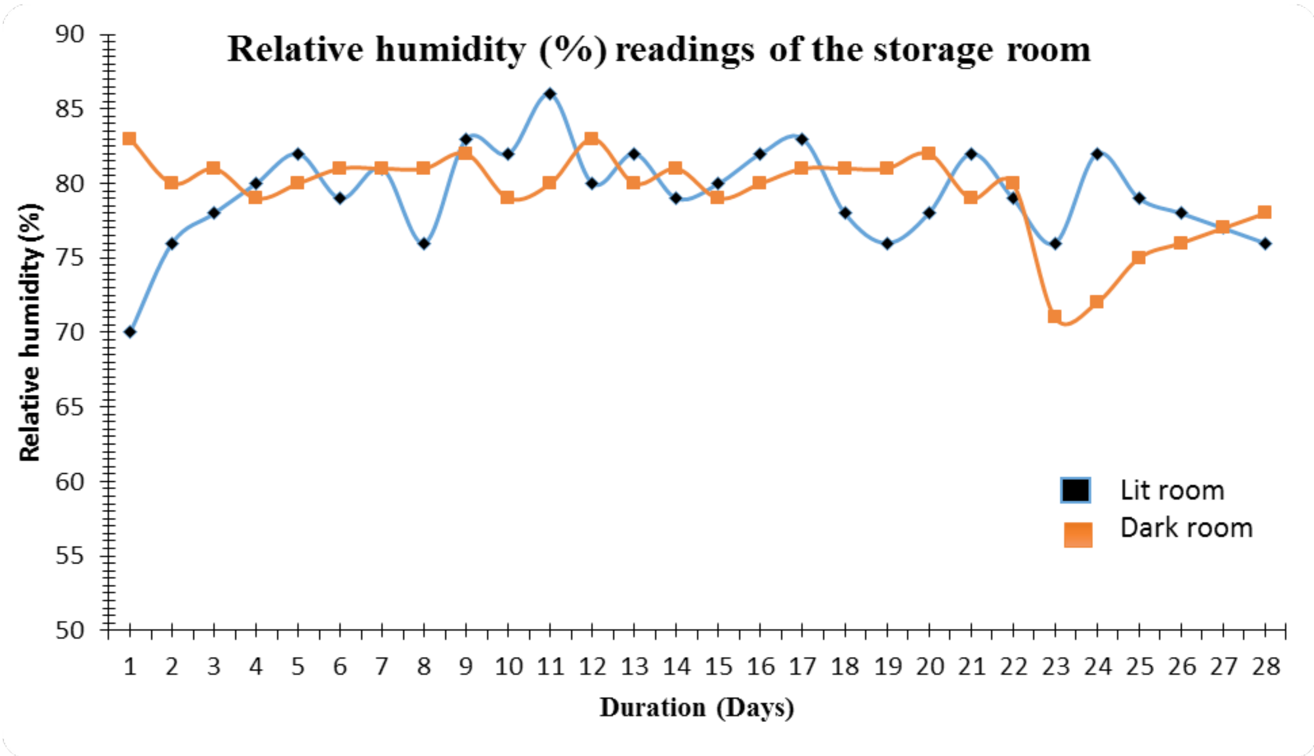

Figure 2. Evolution of relative humidity of the stores (lit vs dark room) against duration of storage (Evolución de la humedad relativa en los almacenes (iluminación vs oscuridad) en función de la duración del almacenamiento).

DISCUSSION

Although, all commercial feeds used had labels which contained information on batch number, date of manufacture and expiry date these information remained unchanged throughout the year. This seems not to reflect the true nutrient contents of the diets as variation in feedstuffs availability with resultant change in ingredients composition was not accounted for. This probably explains why the proprietary finished feeds could not meet the nutritional demands of the

Table I. Nutritional contents of investigated proprietary finished feeds (Contenido nutricional de los piensos comerciales investigados).

Nutrients (g/kg)	Broiler finisher diets			
	A	B	C	D
Declared values				
Metabolizable energy (MJ/kg)	12.12	11.70^{β}	12.12^{β}	12.50
Crude protein	180.00	200.00^{β}	190.00^{β}	185.00
Crude fat	60.00	100.00$^{\#}$	100.00$^{\#}$	30.00
Crude fibre	50.00	90.00$^{\#}$	100.00$^{\#}$	50.00
Calcium	10.00	10.00^{β}	1.00^{β}	10.00
Available phosphorus	4.00	4.50^{β}	4.00^{β}	7.00
Lysine	8.50	-	-	-
Methionine	3.50	-	-	-
Salt	3.00	-	-	-
Determined values^{a}				
Crude protein	191.50	192.90	188.70	182.70
Crude fat	163.30	95.00	128.30	121.70
Ash	88.30	150.00	122.90	110.00
Dry matter	848.30	875.00	876.70	863.30

^{β}and$^{\#}$: minimum and maximum values indicated by the feed manufacturers, respectively.
^{a} mean values of 8 replicates.

Table II. Variation in feeds colour during storage (Variación en el color de los piensos durante el almacenamiento).

Duration (Week)	Lit room				Dark room			
	A	B	C	D	A	B	C	D
2nd	Yellow	White	Gray	Pinkish white	Yellow	White	Gray	Pinkish white
4th	Yellow	White	Gray	Pinkish white	Yellow	White	Gray	Pinkish white
6th	White	Very pale brown	Light gray	Light gray	White	Gray	Light gray	Light gray
8th	White	Light gray	Light gray	White	Very pale brown	Light gray	Light gray	Light gray

A, B, C, D : Four commercial broiler diets.

animals since the nutrient profile of the feeds is not precisely known.

Proximate analysis revealed significant difference between the declared and determined nutrient profile of the feeds investigated. This discrepancy could not be unconnected to the differences in expected and true nutritive value of the constituent feed ingredients, and portrays ineffective quality control measures during feed manufacturing. Previous researches have also reported significant variation in determined nutrient contents between batches of the commercially-available poultry feeds produced within and between companies (Ru *et al*., 2003; Kudu *et al*., 2008; Uchegbu *et al*., 2009; Idahor and Adua, 2011).This underscores the practice of non-adherence of feed millers to the feed formulation guidelines described by The Codex Alimentarius Code of Practice on Animal Feeding and ineffective enforcement of quality standards by the relevant regulatory bodies.

Observed variation in feed colour among similar feeds stored under different conditions, particularly at 6th and 8th week could be traced to the feeding activity of insects (*Rhyzopertha dominica* F) which would have triggered enzymatic metabolic reactions causing physical and compositional changes while the metabolic wastes released could trigger mould growth. In addition, appearance of frass, dusty particles and webbing in stored feeds which are indication of nutritive loss could be attributed to the feeding activities of insects. Previous studies have shown that light influenced oxidation reaction thereby resulting in altered flavour, colour, texture and nutritive value (Adene, 2004; Uppal *et al*., 2004; Waheed *et al*., 2004). FAO (1980) reported that weight loss and appearance of frass in stored feeds were due to the feeding activity of insects. Metabolic activity of stored insects could create a modified atmosphere with a high CO_2 and low O_2 conditions which, through respiratory heating, could raise the inner temperature of stored feeds thereby destroying inherent amino acids by Maillard reactions when sto-

Table III. Occurrence of insects in broiler finisher diets during storage (Presencia de insectos en las dietas de finalización de pollos de engorde durante el almacenamiento).

Duration (Week)	Lit room				Dark room			
	A	B	C	D	A	B	C	D
2nd	-	+	-	-	-	-	-	-
4th	-	+	+	-	+	-	-	-
6th	+	+	+	+	+	+	+	+
8th	+	+	+	+	+	+	+	+

- : absence of insects; + : presence of insects.
A, B, C, D : Four commercial broiler diets.

Table IV. Effect of feed brands and storage conditions on weight change in storage (%) of broiler finisher feeds (Efecto de las marcas y las condiciones de almacenamiento sobre el cambio de peso en el almacenamiento (%) de los piensos de acabado para pollos de engorde).

Duration (Week)	Lit room				Dark room				SEM	Source of variation		
	A	B	C	D	A	B	C	D		FB	SC	FB*SC
2nd	0.448[a]	0.331[ab]	0.465[a]	0.328[ab]	0.224[b]	0.250[b]	0.063[c]	0.213[b]	0.029	NS	*	*
4th	1.078[c]	0.564[de]	0.434[ef]	1.726[a]	0.726[d]	0.303[f]	0.340[f]	1.275[b]	0.101	*	*	*
6th	2.711[a]	1.135[d]	0.953[d]	2.707[a]	2.490[ab]	0.932[d]	1.261[cd]	1.856[bc]	0.167	*	*	*
8th	2.596[a]	1.950[b]	0.905[d]	3.041[a]	1.975[b]	1.170[cd]	0.766[d]	1.524[bc]	0.163	*	*	*
Total	6.833[b]	3.981[d]	2.757[e]	7.801[a]	5.415[c]	2.656[e]	2.430[e]	4.867[cd]	0.300	*	*	*

[a, b, c, d, e, f]Values in rows with different letters differ significantly ($p \leq 0.05$). *$p<0.05$; NS: Not significant.
A, B, C, D: Four commercial broiler diets (A, B, C and D); FB: Feed brands; SC: Storage conditions; SEM: Standard error of means.

Table V. Effect of feed brands and storage conditions on changes in nutrient content of broiler feeds investigated (Efecto de las marcas y condiciones de almacenamiento sobre los cambios en el contenido de nutrientes en piensos de finalización para pollos de engorde).

Nutrients (%)	Lit room				Dark room				SEM	Source of variation		
	A	B	C	D	A	B	C	D		FB	SC	FB* SC
2nd week												
Moisture content	17.33a	13.26c	14.74b	14.53bc	14.53bc	14.81b	14.88b	14.39bc	0.395	*	NS	*
Crude protein	18.61ab	18.98a	18.78ab	17.91c	18.98a	19.22a	18.83ab	18.31bc	0.185	*	NS	*
Crude fat	17.67a	14.83bc	16.33abc	16.67ab	16.17abc	14.17c	17.50a	15.67abc	0.687	*	NS	*
Ash	13.00ab	15.50a	10.75abc	8.25bc	10.92abc	15.75a	5.75c	15.25a	1.729	*	NS	*
4th week												
Moisture content	18.50ab	18.00bc	19.33ab	20.33a	19.00ab	16.50c	18.50ab	18.33ab	0.586	*	NS	*
Crude protein	18.50ab	18.83a	18.63ab	17.81c	18.87a	19.02a	18.75a	18.18bc	0.173	*	NS	*
Crude fat	12.50bc	13.50abc	14.00ab	12.33c	12.83bc	14.50a	10.50d	13.67abc	0.479	*	NS	*
Ash	15.50abc	18.35a	10.50e	11.87de	12.75cde	18.00a	14.17bcd	16.58a	1.114	*	NS	*
6th week												
Moisture content	24.92	22.32	21.45	21.69	24.38	20.33	24.59	21.23	1.842	NS	NS	NS
Crude protein	21.14	21.14	21.72	20.70	22.08	21.43	21.39	21.60	0.584	NS	NS	NS
Crude fat	6.33b	7.50ab	5.83b	6.33b	8.67ab	9.77a	6.17b	8.00ab	0.855	*	*	*
Ash	8.00d	20.71ab	16.50bc	12.50c	14.85c	22.25a	17.00bc	17.25bc	1.463	*	*	*
8th week												
Moisture content	28.75a	25.75ab	26.64ab	25.03ab	28.13ab	23.47b	26.26ab	25.61ab	1.413	*	NS	*
Crude protein	19.13c	19.73ab	20.01a	19.21bc	19.68abc	19.45abc	19.66abc	19.60abc	0.173	NS	NS	*
Crude fat	6.17c	7.00bc	5.83c	6.00c	9.50a	7.33bc	8.67ab	7.00bc	0.562	NS	*	*
Ash	18.25b	22.18a	17.25b	17.00b	16.18bc	24.50a	13.50c	21.83a	0.966	*	NS	*

a, b, c Values in rows with different letters differ significantly ($p \leq 0.05$). *$p<0.05$; NS: Not significant.
A, B, C, D: Four commercial broiler diets (A, B, C and D); FB: Feed brands; SC: Storage conditions; SEM: Standard error of means.

red for a long period of time. Furthermore, the energy content of the feeds could also be degraded while the apparent loss of trace minerals and vitamins might have resulted in a level below that recommended for broiler chickens (Maciorowski *et al*., 2006). Furthermore, observed physical changes in stored diets might occur as a result of mould growth and consequently, mycotoxins production. According to Varga and Toth (2005), feeding of stale or mouldy feeds may lead to substantial economic losses due to feed refusal, poor feed conversion, diminished body weight gain, immunosuppression, interference with reproductive capacities and residues in animal products.

Significant decrease in weight loss obtained in feed C could be attributed to the feed form (Pellets). This implies that pellets had longer storage shelf-life compared to mash diets. This is because many of the damaging factors would have been destroyed due to heat treatment during pelleting. Most farmers believed that the use of pellet feeds reduce feed wastage by birds. Longer shelf-life might be another intrinsic factor that motivates farmer's preference. Although pellet quality may appear adequate immediately after leaving the feed mill, pellet quality at the time the flock is consuming the feed in the house is very important.

Among the mash diets, however, least ($p<0.05$) weight loss was obtained in feed B. This could be attributed to the relatively higher dry matter content of the feed. It is therefore advisable to keep moisture content of finished feeds as low as possible. Also, since most of the proprietary feeds available for broiler chickens are in mash form, it is hereby suggested that anti-oxidants and preservatives should be included in order to minimize weight loss and prolong their shelf-life during storage.

Higher crude fat and ash contents obtained in feeds stored under dark room could indicates delayed deterioration of labile nutrients and longer shelf life of feeds. This finding is in congruence with the reports of Reddy (2001) and Waheed *et al*. (2004) who found that light speeded up feed spoilage process causing reduced nutrient composition of the feeds through oxidative rancidity. Progressive increase in moisture content (MC) and crude protein (CP), particularly at the 6th week, could be attributed to the presence and feeding activity of insects. Reddy (2001) had reported that metabolic activity of insects, and even micro-organisms, would produce metabolic heat and water which could contribute to an increase in temperature and moisture content of the stored feed and trigger mould growth thereby rendering such feeds unfit for use. This findings is strongly supported by Bodroža-Solarov *et al*. (2010) who reported increase in MC and CP of spelt wheat infested by rice weevils and lesser grain borer. Increased MC could have elevated the available water in the feed matrix thereby increasing the rate of survival and proliferation of microbes, thus causing caked and mouldy feeds (Maciorowski *et al*., 2006).

Higher CP and ash contents could also be attributed to the presence of dead (larvae and adults) insects observed in the feeds at such weeks **(table III)**. Also, higher ash content could partly be attributed to the decomposition of the carbon skeleton of the feeds by the insects through their feeding habits thereby reducing it to dusty particles. Since deterioration and contamination of finished feeds could occur at any stage of production chain, even when formulated diets are wholesome and balanced, it is obvious that the conditions to which they are exposed before being used on the farms could trigger nutrient loss. Therefore, all stakeholders in feed industry are encouraged to adhere strictly to the feed production guidelines as described in the Codex Code of Practice on Animal Feeding, and Quality Assurance (QA) program to ensure delivery of safe and high-quality feeds to the animals.

CONCLUSION

In conclusion, storage conditions produced significant effects on feed quality in terms of colour, storage weight loss and nutrient composition. Proprietary Finished feeds should therefore be properly stored, with minimal exposure to light, so as to maintain their nutrient quality and limit microbial growth.

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