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Zootechnical and Economic Performance of Broiler Chickens Fed with Maize *(Zea mays)* Stored for Twelve Months Using Four Storage Techniques in Burkina Faso

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Abstract

Losses in the nutritional value of maize during storage are a problem for broiler feed in Burkina Faso. The aim of the present study was to evaluate the effectiveness of four storage techniques in improving broiler feed. The experimental set-up used was a completely randomized block with four treatments and three replications. A total of 300 Cobb 500 strain chicks was randomized to four different rations. The rations were based on corn stored in polypropylene bags (PPB), Purdue Improved Crop Storage bags (PICSB) as control, jute bags (JB) and in a traditional mud-brick granary (TMG). After thirty-five days of feeding trial, it was found that the final average body weights of the chickens according to the corn storage technique received were statistically similar. In terms of profitability, the profit margin per chicken for the PPB treatment ($1.01) was higher than the TMG ($0.99), JB ($0.94) and PICSB ($0.85) treatments. These results show that rations based on maize stored in polypropylene and jute bags, and in the traditional banco granary, are better than those based on maize stored in PICSB. However, as far as the granary is concerned, it would be interesting to improve its durability so that it contributes more effectively to the conservation of maize used in poultry feed.

Keywords: Feed conversion indice; Live weight; Mortality rate; Profit margin; Burkina Faso.

Performances zootechniques et économiques de poulets de chair nourris avec du maïs (Zea mays) stocké pendant douze mois selon quatre techniques de stockage différentes au Burkina Faso

Résumé

Les pertes de valeur nutritionnelle du maïs pendant le stockage constituent un problème pour l'alimentation des poulets de chair au Burkina Faso. L'objectif de la présente étude était d'évaluer l'efficacité de quatre techniques de stockage pour améliorer l'alimentation des poulets de chair. Le protocole expérimental utilisé était un plan en blocs complètement randomisés comprenant quatre traitements et trois répétitions. Au total, 300 poussins de la souche Cobb 500 ont été répartis de manière aléatoire entre quatre rations différentes. Les rations étaient composées de maïs stocké dans des sacs en polypropylène (PPB), dans des sacs Purdue Improved Crop Storage (PICSB) servant de témoin, dans des sacs en jute (JB) et dans un grenier traditionnel en briques de terre crue (TMG). Au terme des trente-cinq jours d'essai d'alimentation, il a été constaté que les poids corporels moyens finaux des poulets, selon la technique de stockage du maïs utilisée, étaient statistiquement similaires. En termes de rentabilité, la marge bénéficiaire par poulet pour le traitement PPB (1,01 $) était supérieure à celle des traitements TMG (0,99 $), JB (0,94 $) et PICSB (0,85 $). Ces résultats montrent que les rations à base de maïs stocké dans des sacs en polypropylène et en jute, ainsi que dans le grenier traditionnel « banco », sont plus performantes que celles à base de maïs stocké dans des sacs PICSB. Toutefois, en ce qui concerne le grenier, il serait intéressant d'améliorer sa durabilité afin qu'il contribue plus efficacement à la conservation du maïs utilisé dans l'alimentation des volailles.

Mots-clés : Indice de conversion alimentaire ; Poids vif ; Taux de mortalité ; Marge bénéficiaire ; Burkina Faso.

Introduction

Poultry farming in Burkina Faso is growing significantly (MARAH/DGESS, 2025). It is of great importance to the country, both economically and socially. Indeed, poultry farming plays a key role in reducing food and nutritional insecurity (Mnsi *et al.,* 2024). The contribution of poultry farming to improving living conditions remains far below expectations. Indeed, it struggles to meet the ever-increasing demand for animal products (Awono Bessa, 2008). According to FAO (2019), this strong demand will be further exacerbated by population growth, particularly in urban areas, which could increase from 31% to 50% by 2050. This low rate of poultry production is partly due to high production costs, including feed. Indeed, feed is the major component of poultry and livestock production, representing, according to them, 69% and between 65% and 75% of total recurring production expenses, respectively (Hassan *et al.*, 2016; Dinani *et al.*, 2020). Furthermore, the poor quality of some raw materials also hinders the optimization of farm productivity. Among the main ingredients used is corn, which typically accounts for 50% to 60% of feed for broiler chickens (Jamakhandi *et al.*, 2020). The widespread of the use maize in poultry farming is linked to its high starch and germ oil content, which gives it a high energy value. The total carbohydrate content of maize varies from 60.38% to 78.74% depending on the maize variety (Qamar *et al.*, 2017). However, post-harvest maize is frequently exposed to attacks from insects, rodents, and moulds, which reduce its quality (Gueye, 2012). Furthermore, a study conducted by Zongo *et al.* (2024) showed that maize stored for six months is characterized by abnormal levels of moldy grains, impurities, heterogeneity, and aflatoxins. The use of maize of such quality generally damages poultry, particularly broiler chickens, resulting mostly in stunted growth, reduced feed efficiency, and disease (Liu *et al.*, 2020; Baddi *et al.*, 2021; Defu *et al.*, 2021). Among the many factors that can lead to maize spoilage are storage methods. To reduce the impact of these methods, Idohou (2022) in Bénin Republic reported that the use of jute bags and granaries can reduce pest infestations, especially when the maize is still preserved in its husks. The objective of this study was to determine the effect of maize stored using these techniques and used as an energy source in broiler chicken feed.

Material and methods

Study site

The Guiriko Regional Office of *Centre de Promotion de l'Aviculture et de multiplication des Animaux performants* (CPAMAP), located in Bobo-Dioulasso hosted the experimental study, which took place from January 30 to March 4, 2024. This city is located at 11° 11′ 00″ North and 4° 17′ 00″ West.

Rearing infrastructure and materials

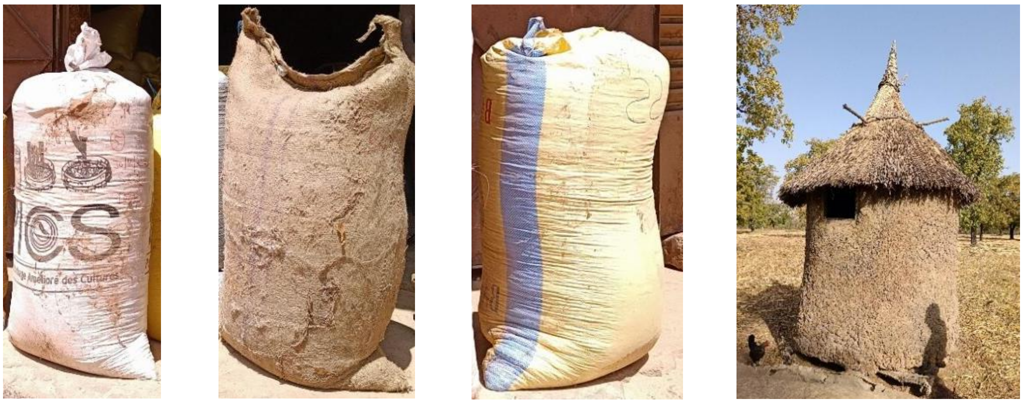
A standard poultry house was used for the trial. It was fitted out and divided into 12 pens of 3 m² each (2 m x 1.5 m). The rearing equipment consisted of waterers, feeders, buckets, electronic scales with a capacity of 20 kg and a precision of 0.1 g.

Animals and plants

Three hundred (300) chickens of the Cobb 500 strain were used for the experiment. At one-day old, their average weight was 40 ± 3,02 g. They were in relatively good health. The SR21 maize variety, grown primarily by farmers in the field, was used for formulating and compounding the diets.

Tools and Infrastructure for Corn Storage

Maize was stored in a traditional mud-brick granary (TMG) located in the municipality of Karangasso-Sambla (Figure 1d). The remaining maize was stored in Bobo-Dioulasso at one of the CPAMAP warehouses. This portion of the maize was packaged in several types of bags: 100 kg in polypropylene bags (PPB) (Figure 1c), 100 Kg in jute bags (JB) (Figure 1b), and 100 Kg in PICSB (Purdue Improved Crop Storage bags) that was the control in this study (Figure 1a).



(a) PICSB (b) JB (c) PPB (d) TMG

PICSB : PICS Bag**, SJ :** Jute Bag**, SPP : P**olyproylene Bag**, GTB :** Tradional Banco Granary

Figure 1 : Corn Storage Tools

Sources of maize used in diets

In total, four rations were formulated based on different storage techniques. The first ration was prepared using corn stored directly in a traditional mud-brick granary (TMG) (figure 1d). The second ration was prepared using corn packaged in polypropylene bags (PPB) (figure 1c), the third using corn packaged in jute bags (JB) (figure 1b), and the last using corn packaged in PICS bags (Control) (figure 1a). To calculate the nutritional values of these feeds, the values of the analyzed corn were used (table 1). The control maize corresponds to harvested and dried maize that has not undergone any storage time.

Table 1: Chemical composition of corn stored in different conditions

Corn	H	DM	TA	OM	CP	Fat	CF	EM/kg.CM	ME/Kg. CM
PICSB (Control)	11.5	88.5	1.04	99	6.36	3.65	2	3929.73	3477.81
PPB	12.4	87.6	0.94	99.1	6.99	3.93	1.7	3980.09	3486.55
JB	11.8	88.2	1.1	98.9	6.92	3.17	1.7	3926.00	3462.74
TMG	12.8	87.2	1.16	98.8	6.81	4.1	1.5	3993.66	3482.47

H: Humidity (%); DM: Dry matter (%); T: Total ash (%); OM: Organic matter (%); CP: Crude protein (%); CF: Crude fiber (%); CM: Crude matter; ME: Metabolisable Energy.

Using the chemical values of the different types of corn, the nutritional values of each ration were calculated. The nutritional values of the four rations are presented in table 2.

Table 2: Calculated Nutrional values (of the different diets (%)

Diets	CP	Fat	ME	Lys	Met	Met+Cys	Ca	P	Na	Cl	CF
Start-up phase											
PICSB	21.20	4.52	3116.83	1.47	0.60	0.96	1.23	0.68	0.13	0.25	3.28
PPB	21.56	4.68	3121.76	1.47	0.60	0.96	1.23	0.68	0.13	0.25	3.11
JB	21.52	4.25	3108.32	1.47	0.60	0.96	1.23	0.68	0.13	0.25	3.11
TMG	21.45	4.77	3119.46	1.47	0.60	0.96	1.23	0.68	0.13	0.25	3.00
Starter phase											
PICSB	21.15	4.32	3076.58	1.44	0.60	0.96	1.20	0.64	0.13	0.25	3.62
PPB	21.51	4.47	3081.51	1.44	0.60	0.96	1.20	0.64	0.13	0.25	3.45
JB	21.47	4.04	3068.07	1.44	0.60	0.96	1.20	0.64	0.13	0.25	3.45
TMG	21.40	4.57	3079.21	1.44	0.60	0.96	1.20	0.64	0.13	0.25	3.33
Finisher phase											
PICSB	18.31	5.24	3152.56	1.17	0.53	0.86	1.20	0.60	0.16	0.29	3.69
PPB	18.67	5.41	3157.68	1.17	0.53	0.86	1.20	0.60	0.16	0.29	3.52
JB	18.63	4.96	3143.75	1.17	0.53	0.86	1.20	0.60	0.16	0.29	3.52
TMG	18.57	5.51	3155.29	1.17	0.53	0.86	1.20	0.60	0.16	0.29	3.40

CP : Crude Protein ; ME : Metabolisable Energy (Kcal/Kg) ; CF : Crude Fiber

Constitution of batches

The chicks were fed for 7 days with a proprietary pre-starter feed. After this period, they were randomly divided into 12 groups of 25 chickens each, and three groups were randomly assigned to each of the treatments: corn-based feeds from PICSB, PPB, JB, and TMG. The average initial live body weights the chickens were 222; 240.44; 242.6 and 235.92g for the PICSB, PPB, JB, and TMG treatments, respectively.

Chicken monitoring

Feed and water were provided *ad libitum*. Refused feed and water were weighed using the electronic scale to determine feed intake. A health protocol was applied to the subjects. This protocol included vaccination against major diseases such as Newcastle disease, Gumboro disease, and infectious bronchitis.

Data collection on weights

Weights were recorded on days 1st, 7th, 14th, 21st, 28th, and 35th. The 14th day was the end of the start-up phase, 28th day the end of the growth phase, and day 35th day the end of the finishing phase. Chickens were weighed at the end of each week in the morning before feed distribution. On day 35, five chickens per batch (15 per treatment, 60 in total) were randomly selected, weighed, and then slaughtered. Slaughter was performed using a knife by severing the jugular vein. Plucking was done manually. After slaughter, the chickens were immersed in hot water at approximately 60°C to facilitate this process. Following these steps, the chickens were eviscerated, their visceral contents removed, and then cut into pieces. The feet, head, carcass weight, empty gizzard, wings, thighs, breast, spleen, heart, and liver were weighed using a precision electronic scale accurate to 1 g.

Zootechnical parameters evaluation

The parameters considered in this evaluation were the Quantity of Feed Consumed (QFC), Average Daily Gain (ADG), Feed Conversion Index (FCI), Mortality Rate (MR), Carcass Yield (CY), and Organ Yield (OG). The following formulas were used to calculate these parameters:

QFC (g/animal) = (Quantity of feed distributed – Quantity of feed remaining) / Number of chicken

ADG (g/day) = (Final live Weight- Initial live weight) / breeding period

FCI (g/g) = Quantity of feed consumed over a period / Weight gain over the period

MR = (Number of deaths / Initial number of animals) × 100

CY = (Carcass weight / Live weight) × 100

OY = (Organ weight / Live weight) × 100

Evaluation of economic parameters

The parameters considered in this evaluation were primarily feed costs, other expenses (purchase of chicks, health monitoring, bedding, gas, hen house depreciation and labor), revenue from the sale of one kilogram of live chicken per treatment, and gross margin. The following formulas were used respectively:

Feed cost per chicken ($) = Quantity of feed consumed × Price per Kg of feed;

Revenue per chicken ($) = Live weight of chicken × Selling price per kg of live chicken;

Gross margin per chicken ($) = Revenue – (Feed cost + other expenses);

Additional gross margin compared to one treatment = Gross margin of one treatment – Gross margin of another treatment.

Data Analysis

Data were processed using Excel spreadsheet version 2016. Data analysis was performed using R software version 4.3.3. The Kruskal-Wallis test was used to separate the means among the four treatments.

Results and discussion

Results

Live weights

The weights of the chickens were statistically similar at the end of the first week. From the second to the fourth week, the mean live weights recorded for the chickens in the four treatments were statistically different ($p \leq 0.05$). However, by the end of the fifth week, there was no longer a significant difference between the treatments. The mean live weights recorded at this time were 1568.8±179; 1632.9±201; 1599.3±178 and 1615.9±218g for the PICSB, PPB, JB, and TMG treatments, respectively (table 3).

Table 3: Evolution of live weights of chicken

Age (week)	Treatments				
	PICSB	PPB	JB	TMG	p-values
1	258.4 ± 20	252.7 ± 23	257.8 ± 26	257.4 ± 24	0.98
2	497.7^{a} ± 46	502.3^{b} ± 47	510.7^{ab} ± 49	487.3^{ab} ± 49	0.03
3	877.7^{a} ± 79	909.6^{a} ± 81	844.3^{b} ± 97	870^{ab}± 91	4.10^{-4}
4	1143^{ab} ± 127	1224.2^{ab} ± 155	1169.3^{a} ± 140	1195.5^{b} ± 159	5.10^{-3}
5	1568.8 ± 179	1632.9 ± 201	1599.3 ± 178	1615.9 ± 218	0.43

Values in the same row assigned the same letter are not statistically different at the 5% ($p > 0,05$) threshold according to the Kruskal-Wallis test.

Average day gain

The average daily gains (ADG) of chicks at the end of the first week following the corn storage technique were statistically similar. From the third to the fourth week, the ADG of the chickens decreased considerably, as shown in table 4, for all treatments except JB. After thirty-five days of breeding, statistical analysis revealed no significant difference between the different treatments ($p > 0.05$). The highest average ADG over the five weeks of breeding was recorded with the PPB treatment (45.51 ± 4.51g/day) and the lowest with the PICSB treatment (43.65 ± 4.37g/day).

Table 4: Averaged body daily weight gain (g) of chickens fed maize in different storage containers

Age (week)	Treatments				
	PICSB	PPB	JB	TMG	p-values
1	31.17 ± 3.12	30.35 ± 3.04	31.09 ± 3.11	31.02 ± 3.10	0.97
2	34.18 ± 3.42	35.66 ± 3.57	36.13 ± 3.61	32.85 ± 3.29	0.40
3	54.18 ± 5.42^{a}	58.19^{b} ± 5.82	47.66^{ab} ± 4.77	54.68^{a} ± 5.47	8.10^{-4}
4	37.9 ± 3.80^{a}	44.94 ± 4.49^{b}	46.43^{b} ± 4.64	46.49^{b} ± 4.65	6.10^{-3}
5	60.82 ± 6.08	58.39 ± 5.84	61.42 ± 6.14	60.06 ± 6.00	0.30
Averages	43.65 ± 4.37	45.51 ± 4.51	44.55 ± 4.45	45.02 ±4.50	0.75

Values in the same row assigned the same letter are not statistically different at the 5 % (p > 0,05) threshold according to the Kruskal-Wallis test.

Feed consumption (FC)

The table 5 shows that the mean feed intake was statistically similar across all four treatments during the five-week breeding period (p > 0.05). Furthermore, it increased for each treatment except for the PICSB treatment at the 4th week. Moreover, at week five, the lowest consumption was observed in the PICSB treatment and the highest in the TMG treatment. Throughout the experiment, each chicken consumed an average of 78.92±15.78 g; 82.88 ±16.56 g; 79.73 ±15.94 g; 81.97±16.22 g for the PICSB, PPB, JB, and TMG treatments, respectively.

Table 5: Average feed consumption per chicken

Age (week)	PICSB	PPB	JB	TMG	p-values
1	26.9±5.4	26.9±5.4	26.9 ±5.4	26.94 ±5.4	0.99
2	56.6^{a} ±11.3	61.3^{a} ±12.3	58.35^{a} ±11.7	59.6^{a} ±11.1	0.91
3	93.6 ±18.7	95.9 ±19.2	88.7 ±17.7	93.4 ±18.7	0.71
4	92.0^{ab} ±18.4	102.2^{a}±20.4	96.5^{b} ±19.3	101.4^{a} ±20.2	0.03
5	125.5 ±25.1	128.1 ±25.6	128.2 ±25.6	128.5 ±25.7	0.98
Averages	78.92 ±15.78	82.88 ±16.56	79.73 ±15.94	81.97±16.22	0.88

Values in the same row assigned the same letter are not statistically different at the 5 % (p > 0,05) threshold according to the Kruskal-Wallis test.

Feed Conversion Indice

The storage method did not have a statistically significant effect on the feed conversion ratio (FCR) of the chickens (p > 0.05). However, the analysis showed that the highest FCR was observed in the PICSB treatment (1.81) and the lowest in the JB treatment (1.75). During the five-week trial, the highest mean FCR was observed in the fourth week. At this time, the PICSB treatment (2.43) had the highest value (table 6).

Table 6: Feed conversion indice per chicken

Age (week)	Treatments				
	PICSB	PPB	JB	TMG	p-values
1	1.11 ± 0.17	1.14 ± 0.17	1.12 ± 0.17	1.12 ± 0.17	0.97
2	1.65 ± 0.25	1.72 ± 0.26	1.61 ± 0.24	1.81 ± 0.27	0.4
3	1.75 ± 0.26	1.61 ± 0.24	1.86 ± 0.28	1.71 ± 0.26	0.65
4	2.43 ± 0.36	2.27 ± 0.34	2.08 ± 0.31	2.21 ± 0.33	0.3
5	2.12 ± 0.32	2.18 ± 0.33	2.09 ± 0.31	2.11 ± 0.32	0.77

Values in the same row assigned the same letter are not statistically different at the 5 % (p > 0,05) threshold according to the Kruskal-Wallis test.

Mortality rate

No significant difference was observed in the mortality rates of the different treatments ($p>0.05$). Over the 35 days of the trial, the mortality rate was 5.33% for all treatments. Furthermore, after five weeks of rearing, the PPB treatment (5.56%) recorded the highest mortality rate, followed by the TMG treatment (1.39%), as illustrated in table 7.

Table 7 : Mortality rate of chickens fed maize stored under different storage condions

Age (week)	Treatments				
	PICSB	PPB	JB	TMG	p-values
1	$2.67^a \pm 0.49$	$2.67^a \pm 0.49$	$2.67^a \pm 0.49$	$2.67^a \pm 0.49$	0.99
2	0	0	$1.37^a \pm 0.38$	0	0.75
3	0	$1.37^a \pm 0.38$	0	0	0.75
4	0	0	0	$1.37^a \pm 0.38$	0.85
5	0	$5.56^a \pm 0.79$	0	$1.38^a \pm 0.38$	0.60
Overall mortality	2.66 ± 1.03	9.33 ± 2.73	4 ± 1.26	5.33 ± 1.51	0.32

Values in the same row assigned the same letter are not statistically different at the 5 % (p > 0,05) threshold according to the Kruskal-Wallis test.

Carcasses weight and organs weight

Data analysis revealed no significant differences between the various treatments. However, the carcass, breast, leg, wing, and gizzard weights were slightly better in the TMG treatment compared to the other treatments. The PICSB treatment recorded the lowest values (table 8).

Table 8: Carcasses and organs weight of chickens

Parameters	Treatments				P-values
	PICSB	PPB	TMG	JB	
Carcass Weight(g)	1184.9±58.8	1288.4±113.7	1322.6±53.2	1238.3±70.5	0.06
Carcass Yield (%)	66.1±1.8	66.7±3.1	66.51±2.1	67.2±2.8	0.82
Breast Weight (g)	150.8±17.3	160.1±21.0	170.3±19.7	157.5±17.1	0.62
Thigh weight (g)	259.5±11.1	289.1±30.9	296.5±16.5	275.3±27.1	0.77
Gizzard weight (g)	59.5±7.1	57.7±5.5	64.3±9.7	55.1±8.7	0.91
Wing weight (g)	71.7±3.7	75.5±4.5	79.3±4.9	76.5±5.3	0.95
Heart weight (g)	7.2±1.8	9.4±1.4	8.9±1.2	9.1±2.4	0.84
Liver weight (g)	37.5±5.8	41.8±7.7	38.8±6.9	34.9±4.5	0.89

Economic evaluation

At the end of the study, the economic analysis revealed a higher feed cost for the PPB treatment compared to the other treatments (Table 9). It also recorded the highest production cost. However, it resulted in the best gross margin compared to the other treatments. It was closely followed by the TMG treatment.

Table 9: Estimating the profitability of broiler chickens fed with different rations

	Treatments			
Parameters	PICSB	PPB	JB	TMG
Quantity of feeds consumed (g)				
Pre-start	188.58	188.58	188.58	188.58
Start-up phase	396.27	429.52	408.45	417.48
Growth phase	1299.34	1386.49	1296.33	1363.74
Finishing phase	878.64	896.49	896.56	899.57
Total	2762.83	2901.08	2789.92	2869.37
Feed price per Kg ($)				
Pre-start	1.23	1.23	1.23	1.23
Start-up phase	0.64	0.62	0.64	0.62
Growth phase	0.60	0.58	0.60	0.58
Finishing phase	0.60	0.58	0.60	0.58
Feed cost per chiken ($)				
Pre-start	0.23	0.23	0.23	0.23
Start-up phase	0.26	0.27	0.26	0.26
Growth phase	0.78	0.81	0.77	0.79
Finishing phase	0.53	0.52	0.54	0.52
Total ($)	1.80	1.83	1.80	1.80
Others charges ($)				
Cost of chicks	1.12	1.12	1.12	1.12
Veterinary care	0.25	0.25	0.25	0.25
Cost of litter	0.08	0.08	0.08	0.08
Cost of gas for heating	0.12	0.12	0.12	0.12
Poultry house depreciation	0.17	0.17	0.17	0.17
Salary	0.17	0.17	0.17	0.17
Total ($)	1.91	1.91	1.91	1.91
Total charges ($)	3.71	3.74	3.71	3.71
Averarage live weight (g)	1568.8	1632.9	1599.3	1615.9
Live weight price per kg ($)	2.91	2.91	2.91	2.91
Chicken price ($)	4.56	4.75	4.65	4.70
Gross margin per chicken ($)	0.85	1.01	0.94	0.99

Discussion

The chick's weight at one-day old was 40 g. This weight was lower than those observed by other authors, which were 41.7 g, 42 g, and 43 g (Hien *et al.*, 2012; Hien *et al.*, 2018; Zongo, 2019). However, the weight obtained was similar to the 38 to 45 g range indicated by CIRAD-GRET (2002). At the end of the trial (35 days of age), the highest mean live weight was observed in the PPB treatment group (1,632 g ± 200). This weight was lower than the 2,000 g observed at 37 days in Switzerland (Hoffmann *et al.*, 2013). However, the recorded weight was higher than the 1,056 g found by Zongo (2019) in Burkina Faso. It was also higher than the weight reported by CIRAD-GRET (2002), which is between 1,300 and 1,500 g at 35 days. No significant difference was observed between the average weights of the different treatments. However, in terms of absolute values, the chickens in the PPB (1,632 g ± 200), TMG (1,616 g ± 218), and JB (1,599g ± 178) treatments had higher average live weights than those in the PICSB treatment (1,569g ± 179). This performance indicated the significant impact that storage method can have on maintaining corn quality during storage. Laboratory analyses of the maize also revealed higher protein and mineral content for polypropylene bags, jute bags, and the traditional banco granary compared to the PICSB. With these storage methods, the maize germ is certainly better preserved, as it contains, according to the FAO (1993), a high content of crude fat, minerals, and a relatively high protein content.

During the trial, a decrease in average daily gain was observed in chickens from the different treatments between the third and fourth weeks. This decrease was likely due to prolonged heat stress during the fourth week, which led to reduced feed intake and consequently, weight gain. This confirms the findings of Baracho *et al.* (2018), who concluded that environmental factors, particularly thermal comfort and air quality, have a significant influence on ADG. The ADG recorded in the PICSB treatment was the lowest among the different treatments. This result can be attributed to the reduced nutritional value of the maize stored in this type of bag.

Over the 35 days of rearing, the highest average daily gain (ADG) was recorded in the PPB treatment. This value was lower than the 44.75 g/day obtained by Zongo (2019). However, the ADG obtained with this treatment was higher than the 39.9 g/day observed by Hien *et al.* (2018). Poor herd management (feeding, health, and hygiene) may explain this low performance, as mentioned by Suwarta and Darmadji (2020).

The comparison of average feed intake between treatments revealed no statistically significant difference from the first to the fifth week, except for the fourth week. However, the average feed intake recorded by chickens in the PPB and TMG treatments was higher than that of the two PICSB treatments, particularly during the cumulative growth and finishing phases. This variability in feed intake was likely linked to a much higher fat content in these two types of maize. Indeed, according to Lindsay (2023), fats improve feed palatability and are necessary for energy and the absorption of fat-soluble vitamins. Throughout the rearing period, the highest average feed consumption was observed in the PPB treatment group (82.88 g). This consumption value was lower than the 96.12 g/day, 89.69 g/day, and 99.80 g/day observed by Tossou *et al.* (2014), Zongo (2019), and Ouedraogo (2017), respectively. This result could be attributed to the breeding period coincided with the beginning of the hot dry season (February to March), when the average temperature was around 36°C with a peak of 40°C. Mazzoni *et al.* (2022) noted that heat stress lead to a reduction in feed consumption due to a loss of appetite resulting from morphometric alterations not only in the small intestine but also in a key organ such as the proventriculus.

The storage method had no statistically significant effect on the feed conversion ratio (FCR) of the chickens ($p > 0.05$). During the five weeks of rearing, the highest FCR was observed in the JB treatment, with a value of 1.75. This value was higher than that recommended by Larbier and Leclercq (1992) and CIRAD-GRET (2002), which was 1.7. The high FCR level could be linked to rearing conditions, particularly feed waste, disease, and heat stress. This is corroborated by the results of Aviagen (2012), which indicated that these various observed factors are likely to reduce feed intake, growth rate, or the health status of broiler chickens and thus affect FCR. Regarding the specific case of food waste, the lack of pelleting is one of the factors that contributed to its increase. Indeed, according to CIRAD-GRET (2002), pelleting can promote consumption and help limit food waste and sorting.

The lowest feed conversion ratio (FCR) was observed in the PICSB treatment (1.81). This result was likely linked to the low nutritional value of the corn used in the feed. Aviagen

(2012) confirms this, highlighting in his article the quality of the raw materials used in broiler feed production was a factor influencing the FCR.

The average mortality rate across all treatments was 5.33%, with the highest rate observed in the PPB treatment (5.56%). This result can be attributed to high average temperatures, especially during the last three weeks (36°C), and the higher weight of the chickens, which was greater in the PPB treatment. Indeed, Lohmann (2011) and Boudouma and Tiefiel (2012) highlighted that the highest mortality rates are observed in cases of heat stress, particularly in heavy hens, due to suffocation. Furthermore, the rates recorded across all treatments and in the PPB treatment was higher than the acceptable standard recommended by Arbelot and Dayon (1997), which is 3 to 5%. These rates were also higher than the 1.2% and 1% observed by Hien *et al.* (2012) and Zongo (2019), respectively. However, both observed rates fall within the 5 to 8% range recommended by CIRAD-GRET (2002) for hot climates. Furthermore, it was slightly lower than the 6.28% obtained by Hien *et al.* (2018).

At 35 days of age carcass weights in the TMG treatment compared to the other three treatments (PICSB, PPB, and JB) was slightly better. This promising result could be attributed to the slightly higher energy level of the feed in this treatment. Indeed, according to Akbari *et al.* (2022), high-energy diets lead to increased carcass weight and breast muscle development in broiler chickens. The highest carcass yield (67.19%) was obtained with the JB treatment. This rate was below compared to the 70-72% range indicated by CIRAD-GRET (2002). The highest weight for the breast meat (170 g) was obtained with the TMG treatment. This weight, however, was slightly higher than the 160 g recommended by CIRAD-GRET (2002).

In poultry farming, the highest costs were observed with the PPB treatment. This is directly related to the slightly higher feed consumption compared to the other treatments. However, with an average live weight of 1632.9 g, the sales revenue for this treatment was slightly higher at $4.75 per chicken. This was followed by the TMG ($4.70) and JB ($4.65) treatments, and then the PICSB ($4.56) treatment, which recorded the lowest revenue.

Thus, the profit margin obtained with the PPB treatment ($1.01) was better than that obtained with the three other treatments: TMG ($0.99), JB ($0.94), and PICSB ($0.85). The economic performance demonstrated the effectiveness of these maize-based feeds stored in polypropylene bags, in traditional mud-brick granaries, and in jute bags on the economic profitability of broiler chicken farming in Burkina Faso, compared to feeds made from corn stored in PICS bags. These three storage techniques are therefore good ways to maintain the nutritional quality of the corn, which is essential for improving the economic profitability of broiler chicken farms.

Conclusion

The objective of this study was to evaluate the quality of maize stored for twelve months using four different storage techniques and used in broiler chicken feed in Burkina Faso. Among the key findings, it is worth noting that chickens fed with feed incorporating maize stored in polypropylene bags, jute bags, and traditional banco granaries exhibited better economic performance compared to those fed with PICS bags. These results demonstrate the effectiveness of these storage methods in maintaining the quality of maize intended for broiler chicken feed.

However, it would be far more beneficial for the various stakeholders to focus more on adhering to the recommended levels of moisture, impurities, moldy grains, and aflatoxins to ensure the effective use of these tools. Specifically regarding the granary, further improvements are needed, particularly to the roof and foundation, to better preserve the corn, which absorbs significantly more moisture after rain. This traditional practice, despite its shortcomings, deserves greater recognition on the ground to promote local expertise in our country. Unlike the three other storage techniques, the PICS bags, despite their low performance, appear to be much better suited for longer storage periods, given their effective resistance to pests and fungi. Furthermore, these results indicate that using this bag for short- or medium-term corn storage is not truly advantageous compared to the other two types of bags (polypropylene and jute). Based on the various results obtained during this study, particularly for the granary, it is advisable to propose new approaches for constructing this storage infrastructure and to test their effectiveness through trials.

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Conflicts of interest

No conflicts of interest have been declared by the authors for this article.

Authors' contributions declaration

This study was conducted by R.T.Z under the supervision of Professor M.C.V.B and A.K. Then, S.O. and A.Z. help to collect, analyse data and to write the paper.

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