

Effect of partial replacement of fat in sausage diet with different flours at 5%, 10% and 15% level of inclusion on performance, hematological and serum biochemistry of wistar albino rat

Abstract

The demand for functional meats with reduced Animal Fat (AF) has increased globally. Chronic health disorders are often associated with high levels of dietary AF in meat products such as beef sausage (BS). Functional beef sausage (FBS) could be produced with alternative flours as replacer for AF. Effect of partial replacement of fat in sausage diet with different flours at 5%, 10% and 15% level of inclusion on performance, hematological and serum biochemistry of Wistar albino rat was evaluated. The BS (g/100g: beef 65.0, lard 20.0, sodium chloride (SC) 2.0, others 13.0) was used. The FBS were developed using Wheat flour (WF), Irish potato flour (IPF) or corn flour (CF) at 5%, 10% and 15% to replace fat (lard) in beef sausage recipe. Functional properties of the flour were carried out using standard procedure. 60 weaned male albino rats (Wistar strain) weighing between 60 - 62g were purchased. The rats were allotted to 12 dietary treatments with 6 rats per treatment in a completely randomised design. The study lasted 21 days and changes in their body weight were recorded. Feed Intake (FI), Feed Conversion Ratio (FCR), Protein Intake (PI) and Protein Efficiency Ratio (PER) were calculated. At the end of the feeding period, the animals were fasted for 12 hours before blood samples were collected for hematological and serum biochemical analysis. Data were analysed using descriptive statistics and ANOVA at $\alpha_{0.05}$. Irish potato flour was significantly higher in bulk density, oil retention, foaming capacity, oil absorption capacity and emulsion activities compared to other flours. Corn flour was statistically higher ($P<0.05$) in water retention, foam stability and water absorption capacity. Significant differences ($P<0.05$) were observed in all the hematological indices except for red blood cell which had similar values ($P>0.05$). However, there were no consistent trend observed in white blood cell count and its differential counts, which were rather fluctuating. Rats fed Irish potato based sausage had the highest Alanine Amino transferase (ALT) value while rats fed wheat based sausage diet had the lowest ALT of

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Olusegun D Oshibanjo,¹ Akinfolarin B,²
 Opeyemi Adediran,³ Idowu Adesope,³
 Lawrence Abegunde,³ Izang Atang Iliya¹

¹Department of Animal Production, University of Jos, Nigeria

²Nigeria Institute of Animal Science, Nigeria

³Department of Animal Science University of Ibadan, Nigeria

Correspondence: Olusegun D Oshibanjo, Department of Animal Production, University of Jos, Nigeria, Tel +2348055438564, Email oshibnjoo@unijos.edu.ng

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11.87i.u/L. The Aspartate Aminotransferase (AST) assay of rats reveals that rats fed casein-based diet and lard-based sausage had the highest AST values of 7.30i.u/L each with least AST in rats fed protein deficient diet. The urea value for rats on the casein-based diet was the highest (45.29 mg/dL) with least value in rats fed corn-based sausage diet. Rats fed wheat-based sausage had the highest cholesterol (107.97mg/dL), while corn-based sausage had the lowest cholesterol value of 56.16 mg/dL. Corn based breakfast sausage diet was higher ($P<0.05$) in protein efficiency ratio with least score in protein deficient diet. Corn-based sausage had the highest biological value (95.68) with protein deficient diet having the least value (15.49). It was observed that rats fed corn-based breakfast sausage had the highest gained weight of 27g, while rats fed non-protein diet had the lowest weight change of -11g. Replacement of animal fat with corn flour at 10% enhanced better growth performance, hematological and serum biochemistry.

Keywords: beef sausage, animal fat, growth performance, hematological and serum biochemistry

Abbreviations: PER, protein efficiency ratio, AF, animal fat; WF, wheat flour

Introduction

Health challenges such as cardiovascular disease, coronary heart disease, stroke, end stage renal disease and diabetes are being linked to consumers' eating habits and food consumption.¹ Optimal attention is being paid to food consumption which has led to increasing demand for healthier food, especially meat and meat products.² Meat and its products are not the main causes, but the amount of fats that were used during processing. The role of fat as one of the main causes of cardiovascular diseases has been well documented.³⁻⁵ Fat, trans fatty acids (FAs), cholesterol and saturated FAs of meat products have also been associated with obesity and cancer (especially colon, prostate and breast) in developing countries.^{6,7}

The content of cholesterol in meat and meat products is influenced by a variety of different factors, such as type of meat, the cut, and the preparation conditions (broiled, pan fried, boiled etc.). Despite these variations, the concentration of cholesterol generally varies between 75mg and 95mg per 100 g of meat with the notable exception of innards such as kidney, heart, and liver that have significantly higher cholesterol contents at 300-375mg per 100g of meat.⁸ Recommendations for daily allowances generally state that cholesterol intake should be limited to less than 300mg per day.^{8,9} Here, it is important to note that a reduced fat content and its replacement with lean meat does not necessarily decrease the amount of cholesterol in meat products.¹⁰ Rather, in order to prepare meat products that are less in cholesterol and fat, the raw materials used must be replaced with plant materials such as flours, vegetable oils or proteins (Tables 1&2).

Table 1 Binder inclusion level in breakfast sausage

Ingredients (%)	A	B	C	D	E	F	G	H	I	J
Beef	65	65	65	65	65	65	65	65	65	65
Lard	20	15	15	15	10	10	10	5	5	5
Wheat flour	—	5	—	—	10	—	—	15	—	—
Potato flour	—	—	5	—	—	10	—	—	15	—
Corn flour	—	—	—	5	—	—	10	10	—	15
Curing salt	2	2	2	2	2	2	2	2	2	2
Sugar	1	1	1	1	1	1	1	1	1	1
Binder	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Phosphate	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Ice water	4	4	4	4	4	4	4	4	4	4
Dry spices	2	2	2	2	2	2	2	2	2	2
Green spices	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Total	100	100	100	100	100	100	100	100	100	100

Table 2 Diet composition for weanling albino rats fed different flour based sausage

Ingredients	Control	A	B	C	D	E	F	G	H	I	J	K
Casein	11.5	0	0	0	0	0	0	0	0	0	0	0
Glucose monohydrate	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	77.2
Corn starch	68.5	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3
Vegetable oil	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Non nutritive cellulose	1	1	1	1	1	1	1	1	1	1	1	1
Sucrose	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Oyster shell	1	1	1	1	1	1	1	1	1	1	1	1
DCP	2	2	2	2	2	2	2	2	2	2	2	2
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin premix	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sausage	0	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	0
Total	100	100	100	100	100	100	100	100	100	100	100	100

A, 20% lard; B, 15% lard+5% wheat flour; C, 15% lard+5% Irish potato; D, 15% lard+5% corn flour; E, 10% lard+10% wheat; F, 10% lard+10% Irish potato; G, 10% lard+10% corn flour; H, 5% lard+15% wheat flour; I, 5% lard+15% Irish potato; J, 5% lard+15% corn flour; K, nitrogen free diet

Fat is important to the palatability of meat products such as sausage. It also serves as the discontinuous phase of sausage emulsions and is therefore a major structural component that can affect tenderness and juiciness in cooked sausages.¹¹ Consequently, when fat is reduced in meat products they tend to become tough, dry and rubbery, and do not effectively bind water.¹² Carbohydrates such as starches and hydrocolloids are currently added to meat products to improve cooking yields, increase moisture retention and modify product texture.¹³ Potato starches are recommended as water binders in comminuted meat products to increase yields, reduce losses from cooking, improve texture and extend shelf life.¹⁴ Starches are carbohydrate granules of glucose that usually contain amylose, a linear, straight chained

alpha-1,4 glucopyranose polymer and amylopectin, a branched (tumble weed-like) alpha-1,4 glucopyranose polymer with branching components at 1, 6 linkages.¹⁵ Granule size, shape and distribution and the amylose/amylopectin ratio of a starch varies with the plant source, the most common of which are corn, potato, wheat, tapioca and rice.

Alone or the combination of two or more dietary fiber ingredients can be used to reduce fat content in meatproduct,¹ because they are fat dispersible and some also bind. The addition of dietary fiber ingredients that exhibit emulsion, lubricity, and gel texture can successfully replace some portion of fat in meat products. Therefore, this work was aimed to study effect of partial replacement of fat

in sausage diet with different flours at 5%, 10% and 15% level of inclusion on performance, hematological and serum biochemistry of Wister albino rat.

Materials and methods

Location of the study

The experiment was carried out at the Animal Product and Processing (Meat Science) Laboratory of the Department of Animal Science, Faculty of Agriculture and Forestry, University of Ibadan, Ibadan.

Meat source and sausage preparation

Semi-membranous muscle from mature (3-year old) bull and the large intestine of pig were purchased from the slaughter slab of the University of Ibadan Piggery and Cattle units respectively. Lard was purchased from Bodija market (Pig Unit) abattoir. The meat was cleaned; connective tissues and fat were trimmed out of the meat, to make it lean. The meat was kept in the refrigerator at $4\pm1^{\circ}\text{C}$, to lower the microbial load, and also for safety.

$$\text{Forming capacity \%} = \frac{\text{Volume after whipping} - \text{Volume before whipping} \times 100}{\text{Volume before whipping}}$$

$$\text{Forming Stability \%} = \frac{\text{Foam volume after 15 min} \times 100}{\text{Initial foam volume}}$$

Bulk density

50g flour sample was placed into a 100ml measuring cylinder, the cylinder was gently tapped several times, till a constant is achieved according to the procedure of Sosulski et al.,¹⁹ which was modified by Odedeji & Oyeleke¹⁸ The volume of sample is recorded as:

$$\text{Bulk density (g / cm}^3\text{)} = \frac{\text{Weight of sample}}{\text{Volume of sample tapping}}$$

Water absorption capacity

15 ml of distilled water was added to 1g of the flour in a weighed 25mL centrifuge tube; the tube was agitated on a vortex mixer for 2minutes. It was centrifuged at 4000rpm for 20minutes. The clear supernatant was decanted and discarded. The adhering drops of water was removed and then reweighed. Water absorption capacity is expressed as the weight of water bound by 100g dried flour.

Oil absorption capacity

10ml refined corn oil was added to 1g of the flour in a 25 or 80ml centrifuge tube. The tube was agitated on a vortex mixer for 2minutes. It was centrifuged at 4000rpm for 20minutes. The volume of free oil was recorded and decanted. Fat absorption capacity is expressed as mill of oil bound by 100g dried flour.

Water and oil retention

4g of the sample was weighed and 20mL of water or peanut oil was added into a 30mL centrifuge tube. These were stirred occasionally with a glass rod over a 30minutes period. It was centrifuged at 4000rpm for 20minutes. The volume of decanted fluid (water or peanut oil) was measured.

Preparation of binders

Wheat, Irish potatoes and corn were purchased from a reputable market in Ibadan. These were steamed at 80°C for 15 minutes, oven dried to constant weight, then grind into powder form and stored in air- tight containers until use.¹⁶

Functional properties

Functional properties was done according to Bera et al.,¹⁷ as modified by Odedeji et al.¹⁸

Foaming capacity and stability

2g flour sample and 50mL distilled water were mixed in a blender at room temperature. The suspension was stirred for 5minutes at 1000rpm. The total volume after 30seconds was recorded. It was left at room temperature for 30minutes. And the volume of foam recorded were determined according to Bera et al.,¹⁷ and as modified by Odedeji & Oyeleke.¹⁸ The percentage increase in volume after 30 sec was expressed as foaming capacity.

Emulsion activity

2g of sample was blended with 25mL distilled water for 30seconds at 1600rpm. After complete dispersion, refined oil was separated into two burettes and blended until there was a separation into two layers of water and fat. Emulsifying capacity was expressed as oil emulsified by 1g of flour.

$$\text{Emulsion Activity \%} = \frac{\text{Height of emulsified layer} \times 100}{\text{Height of total concentration in the cylinder}}$$

Biological value study

Sixty six (66), 3weeks old weaned albino rats (Wister strain) weighing between 60 - 62g were purchased. The rats were allocated to ten treatments with six rats per treatment in a Completely Randomised Design. The study lasted 21 days. The rats were housed in metabolic cages during the period of the study.

Blood collection and analysis

At the end of the feeding period, the animals were starved of feed for 12hours. Blood samples were collected from throat per replicate for hematological and biochemical analysis. The blood samples were collected from the external ear vein between 7:00am and 9:00am, using a sterilized disposable syringe and needle. Prior to bleeding, a cotton wool was soaked in methylated spirit and used to disinfect the site of collection to prevent infection. An initial 2mL blood was collected into labelled sterile vacutainer tube containing ethylene-diamine-tetra-acetic acid (EDTA) as anticoagulant which was used to determine the hematological components within an hour of sample collection. Another 3-4mls of blood was collected into labeled

sterile sample bottles without anti-coagulant for serum biochemical determination.

The tubes were covered, blood samples were centrifuged at 500rpm (revolution per minute) for 4minutes in an hematocrit centrifuge to obtain serum that was free from cell debris for the biochemical analysis using a spectrophotometer (Available Commercial Kits produced by Sentinel, Italy) at a wavelength of 500nm.

Biuret method of serum total protein determination was employed in this assay as described by Kohn & Allen.²⁰ Albumin was determined using Bromcresol Green (BCG) method as described by Peter et al.²¹ Albumin (Ab) binds with BCG to form a green compound. The concentration of Albumin is directly proportional to the intensity of the green color formed. The globulin concentration was obtained by subtracting albumin value from the value of total protein. The intensity of the blue colour formed was proportional to the protein concentration in the plasma or serum. The albumin/globulin ratio was obtained by dividing the known albumin value by the calculated globulin value. Alkaline Phosphates (ALP), Alanine amino transferase, Aspartate

amino transferase activity were determined using spectrophotometric methods as described by Rej and Hoder.²² The Red Blood Cell (RBC) counts, total White Blood Cell (WBC) counts, hemoglobin (Hb) concentration and Packed Cell Volume (PCV) parameters were determined using a haemocytometer as described by Ewuola and Egbunike.²³

Results

Figures 1&2 show the functional properties of flours used in breakfast sausage as partial fat replacer. Irish potato flour was significantly higher in bulk density, oil retention, foaming capacity, oil absorption capacity and emulsion activities compared to other flours. Corn flour was statistically higher ($P<0.05$) in water retention, foam stability and water absorption capacity. Wheat flour recorded the lowest bulk density, emulsion activities, water retention and water absorption capacity. The hematology of weanling albino rats fed different flour-based breakfast sausage is presented in Table 3. Significant differences ($P<0.05$) were observed in all the hematological indices except for red blood cell which had similar values ($P>0.05$).

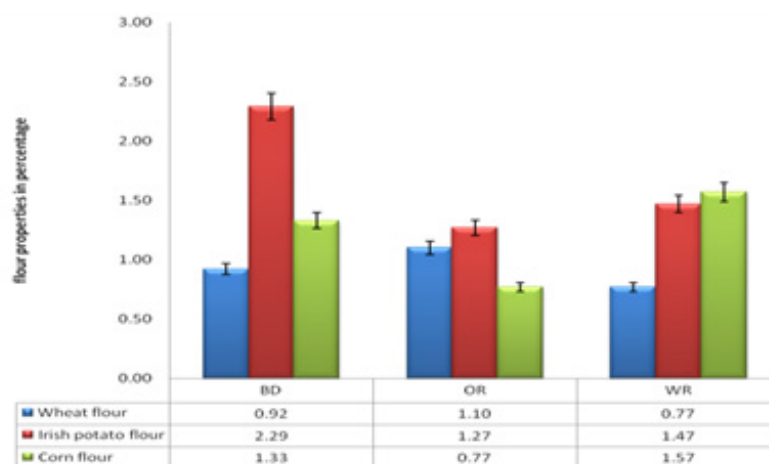


Figure 1 Functional properties of flour used in breakfast sausage.

BD, bulk density; OR, oil retention; WR, water retention

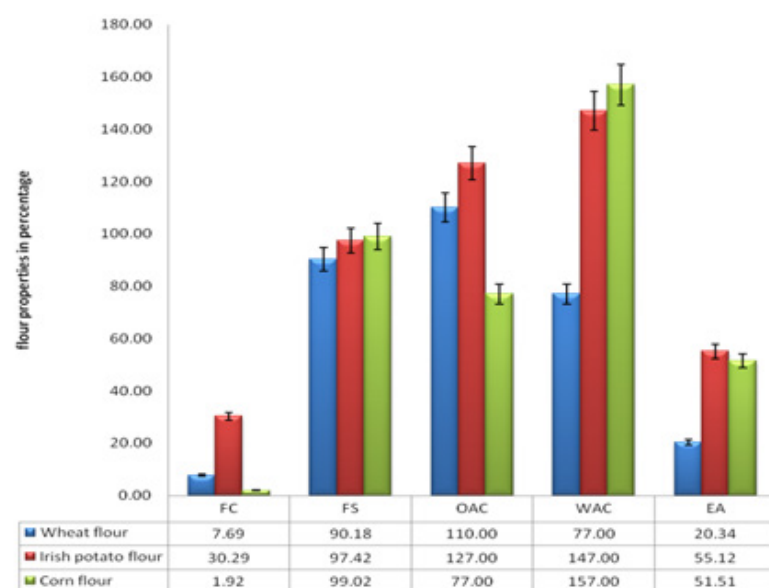


Figure 2 Functional properties of flour used in breakfast sausage.

FC, foam capacity; FS, foam stability; OAC, oil absorption capacity; WAC, water absorption capacity; EA, emulsion activities

Table 3 Haematology of weanling albino rats fed different flour based breakfast sausage

Treatment	PCV (ml%)	Hemo globulin (g/dl)	Globulin (g/dl)	RBC (106/mm ³)	WBC (103/mm ³)	LYM (103/mm ³)	Neut (103/mm ³)	Eosin (103/mm ³)	Mono (103/mm ³)
Control	48.00 ^{ab}	16.00 ^{ab}	32.00 ^{ab}	5.37	4.17 ^{abc}	2.94 ^{ab}	0.92 ^{ab}	0.14 ^{ab}	0.15 ^{ab}
A	40.67 ^b	13.55 ^b	27.11 ^b	6.66	5.17 ^{ab}	3.37 ^{ab}	1.51 ^a	0.10 ^{ab}	0.18 ^a
B	42.67 ^{ab}	14.22 ^{ab}	28.44 ^{ab}	5.78	4.00 ^{abc}	2.86 ^{ab}	0.92 ^{ab}	0.13 ^{ab}	0.09 ^{ab}
C	45.67 ^{ab}	15.22 ^{ab}	30.44 ^{ab}	5.68	2.85 ^c	1.92 ^b	0.76 ^{ab}	0.07 ^b	0.11 ^{ab}
D	46.33 ^{ab}	15.44 ^{ab}	30.89 ^{ab}	6.28	4.05 ^{abc}	2.56 ^{ab}	1.29 ^{ab}	0.11 ^{ab}	0.10 ^{ab}
E	45.33 ^{ab}	15.11 ^{ab}	30.22 ^{ab}	6.31	4.92 ^{abc}	3.32 ^{ab}	1.36 ^{ab}	0.13 ^{ab}	0.11 ^{ab}
F	43.67 ^{ab}	14.89 ^{ab}	29.78 ^{ab}	5.80	3.57 ^{abc}	2.30 ^{ab}	1.12 ^{ab}	0.11 ^{ab}	0.05 ^b
G	47.33 ^{ab}	15.78 ^{ab}	31.55 ^{ab}	6.01	3.87 ^{abc}	2.50 ^{ab}	1.20 ^{ab}	0.10 ^{ab}	0.07 ^{ab}
H	43.67 ^{ab}	14.55 ^{ab}	29.11 ^{ab}	5.90	3.07 ^{bc}	1.94 ^b	0.95 ^{ab}	0.10 ^{ab}	0.08 ^{ab}
I	48.33 ^{ab}	16.11 ^a	32.22 ^a	6.03	2.98 ^{bc}	2.09 ^b	0.69 ^b	0.14 ^{ab}	0.06 ^b
J	48.00 ^{ab}	16.00 ^{ab}	32.00 ^{ab}	6.20	5.65 ^a	3.84 ^a	1.46 ^{ab}	0.20 ^a	0.15 ^{ab}
SEM	0.69	0.23	0.46	1.77	2.26	1.63	0.76	0.01	0.01

^{abc}means on the same row with different superscript were significantly different (P<0.05)

A, 20% lard; B, 15% lard+5% wheat flour; C, 15% Lard+5% Irish potato; D, 15% lard+5% corn flour; E, 10% lard+10% wheat; F, 10% lard+10% Irish potato; G, 10% lard+10% corn flour; H, 5% lard+15% wheat flour; I, 5% lard+15% Irish potato; J, 5% lard+15% corn flour; K, nitrogen free diet; SEM, standard error mean

The packed cell volume (PCV) of rats showed that control diet had highest PCV (48.00ml %) while 20% lard inclusion based sausage had the least (30.86ml %). Similar variation was observed for hemoglobin in control and 20% lard inclusion based sausage were significantly higher in globulin value compared to other diets while non protein diet recorded the lowest globulin value. However, there were no consistent trend observed in white blood cell count and its differential counts, which were rather fluctuating. Table 4 shows the effect of lard replacement with flours on selected serum biochemical indices of weanling albino rats. There were significant differences in the Alanine Amino transferase (ALT) values of rats fed different flour-based breakfast sausages. Rats fed Irish potato based sausage had the highest ALT value while rats fed wheat based sausage diet had the lowest ALT of 11.87i.u/L. The Aspartate Aminotransferase (AST) assay of rats reveals that rats fed casein-based diet and lard-based sausage had the highest AST values of 7.30i.u/L each with least AST in rats fed protein deficient diet. The urea value for rats on the

casein-based diet was the highest (45.29mg/dL) with least value in rats fed corn-based sausage diet. Albumin varied significantly among treatments. Rats fed casein-based diet had the highest albumin value (0.86g/dL), followed by wheat-based sausage (0.76g/dL), lard-based sausage (0.68g/dL), Irish potato-based sausage (0.56 g/dL), corn-based sausage (0.47g/dL) while protein deficient diet had the lowest albumin. Albumin value of rats fed protein deficient diet and corn-based sausage were not statistically different (P<0.05) from each other. Values recorded for total protein showed that rats fed wheat and Irish potato-based sausage diets had the same highest values of 8.99g/dL. Also, it was observed that rats fed lard-based sausage and corn-based sausage had similar (P<0.05) total protein values (7.33 and 7.39g/dl) respectively. Rats fed protein deficient diet had the lowest total protein value of 5.92g/dL. Cholesterol varied significantly (P<0.05) among treatments. Rats fed wheat-based sausage had the highest cholesterol (107.97mg/dL), while corn-based sausage had the lowest cholesterol value of 56.16 mg/dL.

Table 4 Serum biochemistry of selected indices of weanling albino rats fed different flour based breakfast sausage

Treatment	ALT (i.u/l)	AST (i.u/l)	Urea (mg/dl)	Albumin (g/dl)	Total protein (g/dl)	Chol (mg/dl)
Control	23.80 ^b	0.00073 ^a	45.29 ^a	0.86 ^a	8.73 ^c	84.06 ^d
A	19.13 ^c	0.00073 ^a	41.67 ^b	0.68 ^c	7.33 ^h	98.55 ^b
B	13.49 ^e	0.00067 ^d	26.27 ⁱ	0.47 ^h	6.60 ⁱ	74.64 ^e
C	10.51 ⁱ	0.00070 ^b	34.87 ^f	0.37 ⁱ	7.56 ^f	71.38 ^h

Table Continued...

Treatment	ALT	AST	Urea	Albumin	Total protein	Chol
	(i.u/l)	(i.u/l)	(mg/dl)	(g/dl)	(g/dl)	(mg/dl)
D	13.07 ^f	0.00065 ^e	25.31 ^j	0.63 ^d	9.10 ^a	66.67 ^j
E	11.87 ^g	0.00064 ^f	34.59 ^g	0.76 ^b	8.99 ^b	107.97 ^a
F	24.61 ^a	0.00054 ^d	37.82 ^c	0.56 ^e	8.99 ^b	74.28 ^f
G	15.27 ^d	0.00068 ^c	26.50 ^h	0.47 ^h	7.39 ^g	56.16 ^k
H	9.71 ^k	0.00063 ^g	36.12 ^d	0.63 ^d	8.26 ^d	67.39 ⁱ
I	10.71 ⁱ	0.00062 ^h	23.16 ^k	0.51 ^g	7.76 ^e	92.39 ^c
J	10.77 ^h	0.00055 ⁱ	35.10 ^e	0.55 ^f	5.85 ⁱ	73.55 ^g
K	12.97 ^f	0.00016 ^j	22.64 ^j	0.45 ^j	5.92 ^j	79.34 ^e
SEM	0.9	0	1.21	0.02	0.18	2.59

^{abc}means on the same row with different superscript were significantly different (P<0.05)

A, 20% lard; B, 15% lard+5% wheat flour; C, 15% lard+5% Irish potato; D, 15% lard+5% corn flour; E, 10% lard+10% wheat; F, 10% lard+10% Irish potato; G, 10% lard+10% corn flour; H, 5% lard+15% wheat flour; I, 5% lard+15% Irish potato; J, 5% lard+15% corn flour; K, nitrogen free diet SEM, standard error mean

The summary of protein efficiency ratio of weanling albino rats fed different flour based breakfast sausage are presented in Figure 3. Corn based breakfast sausage diet was higher (P<0.05) in protein efficiency ratio with least score in protein deficient diet. Table 5 shows the biological value of different flour based-breakfast sausage fed to weanling albino rats. Corn-based sausage had the highest biological value (95.68) with protein deficient diet having the least value (15.49). The result in Figure 4 showed the feed intake of weanling albino rats fed different flour based breakfast sausage. Reported values differed

significantly (P<0.05) with albino rats fed corn- based sausage diet having the highest feed intake followed by those fed Irish potato based sausage diet. Albino rats fed with no protein diet had the least feed intake value. Figure 5, presents the weight changes of weanling albino rats fed different flour based sausage. It was observed that rats fed corn-based breakfast sausage had the highest weight of 27g, while rats fed non-protein diet had the lowest weight change of -11g (Figure 6).

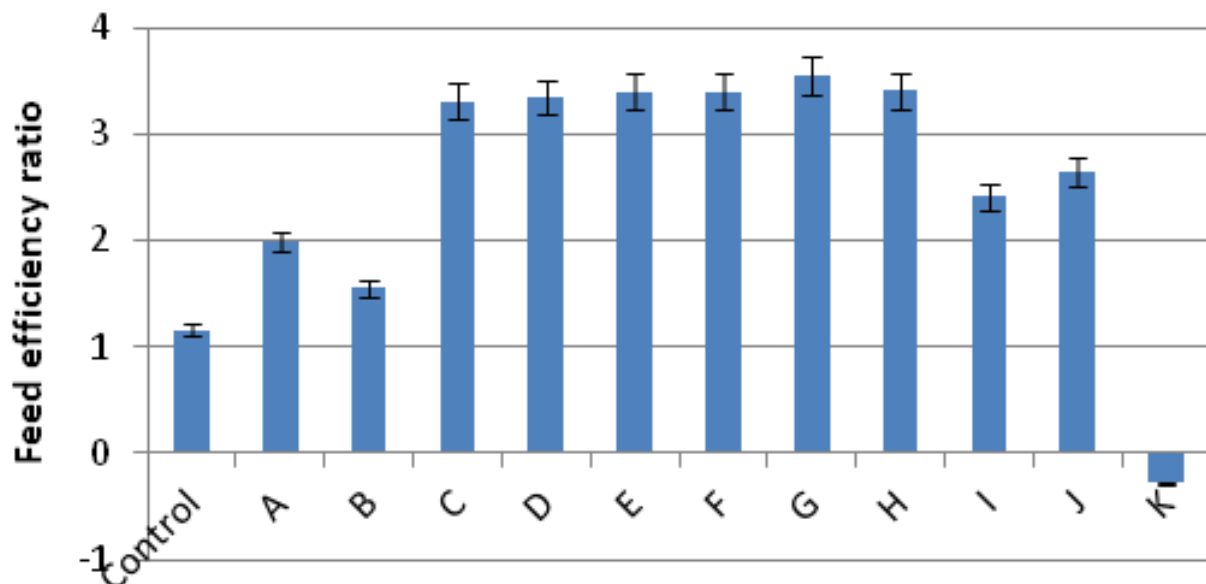


Figure 3 Feed efficiency ratio of weanling albino rats fed different flour based breakfast sausage.

A, 20% lard; B, 15% lard+5% wheat flour; C, 15% Lard+5% Irish potato; D, 15% lard+5% corn flour; E, 10% lard+10% wheat; F, 10% lard+10% Irish potato; G, 10% lard+10% corn flour; H, 5% lard+15% wheat flour; I, 5% lard+15% Irish potato; J, 5% lard+15% corn flour; K, nitrogen free diet

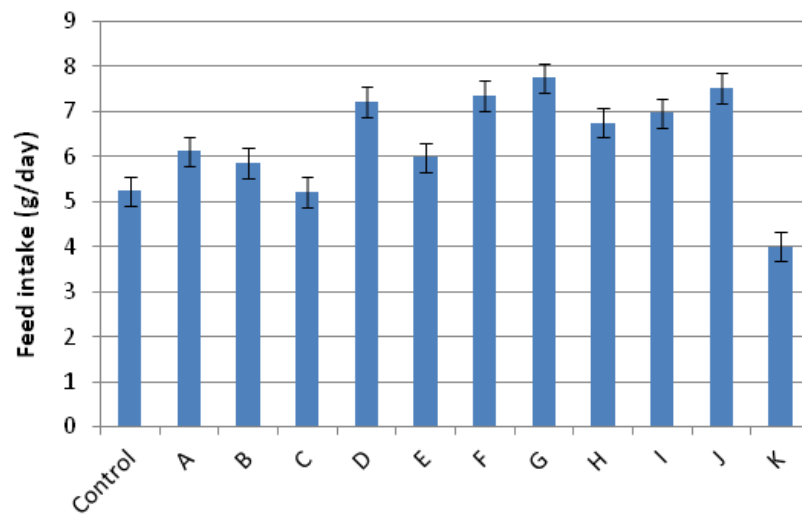


Figure 4 Feed intake of weanling albino rats fed different flour based breakfast sausage.

A, 20% lard; B, 15% lard+5% wheat flour; C, 15% lard+5% Irish potato; D, 15% lard+5% corn flour; E, 10% lard+10% wheat; F, 10% lard+10% Irish potato; G, 10% lard+10% corn flour; H, 5% lard+15% wheat flour; I, 5% lard+15% Irish potato; J, 5% lard+15% corn flour; K, nitrogen free diet

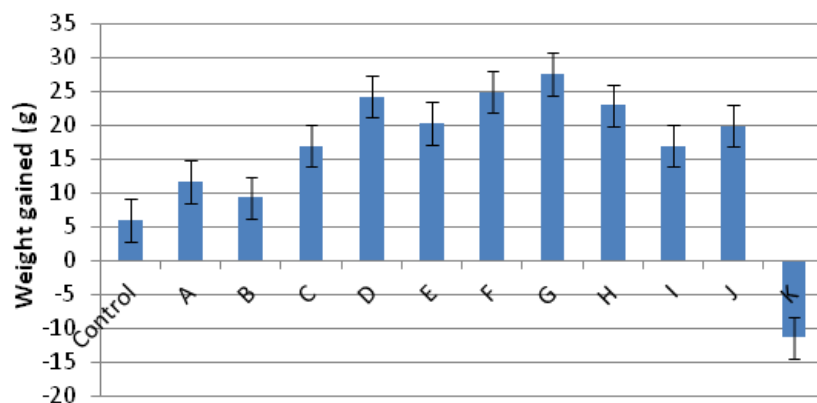


Figure 5 Weight gained of weanling albino rats fed different flour based breakfast sausage.

A, 20% lard; B, 15% lard+5% wheat flour; C, 15% lard+5% Irish potato; D, 15% lard+5% corn flour; E, 10% lard+10% wheat; F, 10% lard+10% Irish potato; G, 10% lard+10% corn flour; H, 5% lard+15% wheat flour; I, 5% lard+15% Irish potato; J, 5% lard+15% corn flour; K, nitrogen free diet

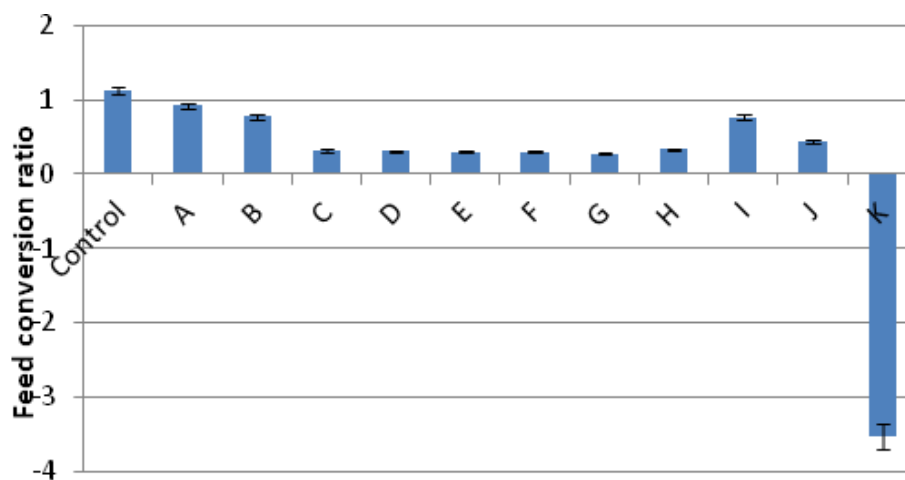


Figure 6 Feed conversion ratio of weanling albino rats fed different flour based breakfast sausage.

A, 20% lard; B, 15% lard+5% wheat flour; C, 15% lard+5% Irish potato; D, 15% lard+5% corn flour; E, 10% lard+10% wheat; F, 10% lard+10% Irish potato; G, 10% lard+10% corn flour; H, 5% lard+15% wheat flour; I, 5% lard+15% Irish potato; J, 5% lard+15% corn flour; K, nitrogen free diet

Table 5 Biological value of weanling albino rats fed different flour based breakfast sausage

Treatment	Biological value
Control	90.15 ^e
A	95.92 ^a
B	91.05 ^{de}
C	93.09 ^{bc}
D	94.06 ^b
E	87.65 ^f
F	92.89 ^{bc}
G	95.68 ^a
H	93.55 ^b
I	91.34 ^{de}
J	92.03 ^{cd}
K	15.49 ^g
SEM	0.42

^{abc}means on the same row with different superscript were significantly different (P<0.05)

A, 20% lard; B, 15% lard+5% wheat flour; C, 15% lard+5% Irish potato; D, 15% lard+5% corn flour; E, 10% lard+10% wheat; F, 10% lard+10% Irish potato; G, 10% lard+10% corn flour; H, 5% lard+15% wheat flour; I, 5% lard+15% Irish potato; J, 5% lard+15% corn flour; K, nitrogen free diet SEM, standard error mean

Discussion

The present study revealed that bulk density was significantly higher in Irish potato flour and lower for wheat flour. Similar result was reported by Baljeet et al.²⁴ Conversely, according to Suresh & Samsher²⁵ wheat flour was found to be significantly higher in bulk density than potato flour. The present study revealed that bulk density depends on the particle size and initial moisture content of flour. Oil retention is the ability of flour to hold on oil which could be influenced by bulk density of the flour. In this study, Irish potato flour had the highest oil retention ability compared to others. This could be due to high bulk density and protein solubility of the flour. Water retention is the ability of flour to hold on water which could be due to the level of protein solubility. Corn flour had the highest value compared to other flour used in this study, which could be due to low bulk density and protein solubility of the flour and higher water absorption capacity.

Foaming capacity is assumed to be dependent on the configuration of protein molecules. Similar trend was reported by Suresh Chandra & Sansher.²⁵ Corn flour recorded the highest foam stability while wheat flour recorded the least foam stability in this study, which could be due to the functions of the type of protein, pH, processing method and surface tension. The oil absorption capacity of flour is equally important as it improved the mouth feel and retains the flavor. The ability of the proteins of flour to bind with oil makes it useful in food system where optimum oil absorption is desired. This makes flour to have potential functional uses in food such as sausage production

Water absorption capacity (WAC) is the ability of flour to associate with water under conditions where water is limited.²⁶ The WAC was observed highest in corn flour followed by Irish potato flour and wheat flour (Figures 1&2). Higher value was reported by Baljeet²⁴ for wheat, and Chandra²⁵ for wheat flour and potato flour. The highest WAC of corn flour could be attributed to the presence of higher amount of carbohydrates (starch). Emulsion activities (EA) related to the ability of flour to bind water and fat together. Emulsion activities were influenced by protein solubility. Highest EA was observed in Irish potato flour with wheat flour possessing the lowest EA. This could be due to protein solubility, pH and concentration.

Protein efficiency ratio (PER) is the ability to support growth in young rapidly growing animals. The low PER observed in lard-based sausage diet, wheat-based sausage diet and Irish potato-based sausage diet is an indication of poor protein content of the diet.^{27,28} Biological value (BV) gives information on how much of the absorbed nitrogen is actually retained or utilized by the body. The BV of rats fed on corn-based sausage was significantly higher [P<0.05] than for rats fed on other diets. This indicates that rats fed on corn-based sausage had higher nitrogen retention than those on other diets. This also suggested that the essential amino acids in the product were present in sufficient quantity to meet the needs for growth. The result obtained in this study is in agreement with reports from Sodipo et al.,²⁹ and Ibironke et al.³⁰

The increase in feed intake is associated with an increase in growth rate of rats fed corn-based sausage diets could be due to a high utilisation of diet containing tested feedstuff with less anti-nutritional factor present in corn, compared to wheat-based sausage diet with decrease in feed intake and lesser weight gained could be due to a poor utilisation of diet containing tested feedstuff. In this study, feed intake and weight changes obtained were paralleled to one another. As feed intake increases, weight changes and gained increased while decrease was observed in feed conversion ratio. It was observed, that there were significant difference in the Alanine Amino transferase (ALT), Aspartate Aminotransferase (AST), albumin, total protein and cholesterol result showed statistical different from each other, with rats fed wheat-based sausage having the highest cholesterol (107.97mg/dl), while corn-based sausage had the lowest cholesterol value of 56.16 mg/dl. According to Solomon et al.,³¹ and Adam³² AST and ALT activities into the blood stream significantly increase in a toxic environment. In rats, 90% of AST are present in holoenzyme form.

Summary of packed cell volume of WAR fed different flour based breakfast sausage shows that control diet had the highest value (48.00%) while 20% lard inclusion based sausage had the least packed cell volume (30.86%). Similar variation was also obtained for hemoglobin, control and lard-based sausage were significantly higher in globulin value compared to other diet while non-protein diet recorded the lowest globulin value. However, there were no consistent trend observed in white blood cell count and its differential counts, but rather fluctuating in pattern. The protein-deficient diet caused a significant reduction in the packed cell volume titre, red blood cells count titre as well as hemoglobin titre values of the Wistar rats fed this diet. On the other hand, casein-based diet elicited similar blood characteristics in the other groups of rats fed sausages manufactured from wheat, Irish potato, corn flours. White blood cells are known to help protect the internal environment of living systems against

intruding pathogens (antigens) from setting off pathological conditions. This may have been as a result of the response of the animals to an immunological challenge absent in the other experimental group of animals. It is also possible that certain components of the feeding materials were foreign in the digestive physiology of these group of experimental animals. In a study conducted by Egbung, ²³ it was observed that there was a significant decrease in the WBC of rats fed trans-fatty acid diets compared to those on the control diet. This trend was however not the case in the present study as only two experimental group of animals showed deviation while other groups showed no deviation. ^{33–36}

Conclusion

Replacement of animal fat with corn flour at 10% enhanced better growth performance, hematological and serum biochemistry which can prevent and reduce the health challenges such as cardiovascular disease, coronary heart disease, stroke, end stage renal disease and diabetes are being linked to consumers' eating habits and food consumption.

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Conflicts of interest

Author declares there are no conflicts of interest.

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