Nig. J. Anim. Prod. 2021, 48(5):186-202. https://doi.org/10.51791/njap.v48i5.3199 Nigerian Journal of Animal Production

Nutritional potentials and reproductive effects of Irish potato (*Solanum tuberosum)* peels on male Wistar rats

Akinsulie O. C., *Akinrinde A. S., Soetan K. O.
Department of Veterinary Physiology and Biochemistry, University of Ibadan, Ibadan, Nigeria
Corresponding author: as.akinrinde@mail.ui.edu.ng; as.akinrinde@gmail.com;+234(0)7064368126

Abstract

Increasing demand and high cost of conventional animal feed and ingredients have stimulated the search for sustainable alternatives in substances otherwise considered as agricultural or industrial wastes. The present study evaluated the nutritional properties of Irish Potato agro-wastes (peel) (IPP) as an alternative source of feed nutrients, via its effects on haematological, biochemical, antioxidant and reproductive indices using Wistar rats as experimental animal model. Twenty male Wistar rats (100-120 g) were randomly allocated to two dietary treatment groups A and B, with 10 rats in each group. Group A (control) were fed a commercial rat concentrate while Group B rats were fed processed Irish potato peel diet for 2 weeks. The proximate analysis of the diets revealed lower levels of crude protein, energy, fat and ash in IPP, but higher levels of crude fiber, dry matter, moisture and Nitrogen free extract, compared to the control diet. However, IPP recorded lower levels of major anti-nutritional factors (Trypsin Inhibitor, Cyanogenic glycosides, Phytates, Oxalates) compared to the commercial diet. Although IPP led to a significant reduction in the body weights of the rats, there were no changes recorded in most haematological (PCV, Hb, RBC, Platelet count, MCV, MCH and MCHC) and serum chemistry (ALT, AST, ALP) parameters between IPP-fed and control rats. There were observable increases in the activities of antioxidant enzymes (Superoxide dismutase and Glutathione peroxidase) and some markers of oxidative stress (Hydrogen peroxide and Malondialdehyde), as part of a possible adaptive response to IPP. Furthermore, histopathological examination of the liver, kidney and testes did not present any major lesions in both groups of rats, although significant enhancement of sperm motility, livability and sperm count was observed in the IPP-fed rats compared to the control group. This study demonstrates that Irish potato peels possess promising nutritional potentials that should encourage its utilization as an alternative source of animal feed ingredients.

Keywords: *Irish potato peels; Agro-waste; Antioxidants; Nutrients; Anti-nutritional factors*

Poteurs nutritionnels et effets de reproduction de la pomme de terre irlandaise (Solanumtuberosum) sur les rats Wistar masculins

Résumé

La demande croissante et le coût élevé des aliments et d'ingrédients des animaux conventionnels ont stimulé la recherche d'alternatives durables dans des substances autrement considérées comme des déchets agricoles ou industriels. L'étude actuelle a évalué les propriétés nutritionnelles des déchets d'agro-pommes de terre irlandaise (peau) (IPP). Source des nutriments alimentaires, via ses effets sur les indices hématologiques, biochimiques, antioxydants et de reproduction utilisant des rats wistar comme modèle animal expérimental. Vingt rats Wistar mâles (100-120 g) ont été alloués au hasard à deux groupes de traitement alimentaire A et B, avec 10 rats dans chaque groupe. Le groupe A (contrôle) a été nourri un concentré de rat commercial, tandis que les rats de groupe B ont été alimentés dans un régime alimentaire de pelage de la pomme de terre irlandais pendant 2 *semaines. L'analyse proximité des régimes a révélé des niveaux inférieurs de protéines brutes, d'énergie, de graisse et de cendres dans l'IPP, mais des niveaux plus élevés de fibres brutes, de matière sèche, d'un extrait d'humidité et d'un extrait sans azote, par rapport au régime de contrôle. Toutefois, l'IPP a enregistré des niveaux inférieurs de facteurs anti-nutritionnels majeurs (inhibiteur de la trypsine, glycosides cyanogéniques, phytates, oxalates) par rapport au régime commercial. Bien que l'IPP a conduit à une réduction significative des poids corporels des rats, il n'existait aucun changement enregistré dans la plupart des paramètres hématologiques (PCV, HB, RBC, RBC, MCV, MCH et MCHC) et la chimie sérique (ALT, AST, ALP). entre les rats nourris IPP et les rats de contrôle. Il y avait des augmentations observables des activités des enzymes antioxydantes (superoxyde de distinctement et de la peroxydale de glutathione) et de certains marqueurs de stress oxydatif (peroxyde d'hydrogène et malondialdéhyde), dans le cadre d'une réponse adaptative possible à IPP. En outre, l'examen histopathologique du foie, des reins et des testicules n'a présenté aucune lésion majeure dans les deux groupes de rats, bien que l'amélioration significative de la motilité des spermatozoïdes, de la vie privilégiable et du nombre de spermatozoïdes a été observée dans les rats alimentés par le IPP par rapport au groupe témoin. Cette étude démontre que les peaux de la pomme de terre irlandaise possèdent des potentiels nutritionnels prometteurs qui devraient encourager son utilisation en tant que source alternative d'ingrédients alimentaires pour animaux.*

Mots-clés: Peluches irlandaises; Agro-déchets; Antioxydants; Nutriments; Facteurs antinutritionnels

Introduction

Over the years, there has been an over-dependence on grains as the major source of energy in animal feeds in Nigeria. Increasing demand and subsequent high cost of conventional animal feed and ingredients has spurred some subtle competition between animals and humans thereby creating the need for sustainable alternatives (Ojebiyi *et al*., 2010). Nigeria was ranked the fourth biggest producer of potato in Sub-Saharan Africa with a production yield of thousands of tons per year (Ugonna *et al*., 2013). Recent estimate of Irish potato production in Nigeria stands at a yield per hectare of about 3.7 tons (Uche *et al*., 2020). Indiscriminate discard of agricultural waste causes harmful effects in the environment and, in many parts, the peels of food crops are now considered as an alternative feed because of their potential health benefits (Gebrechristos *et al*., 2018). Moreso, there are lingering issues of waste disposal and recycling in Nigeria and Africa as a whole. Irish potato (*Solanum tuberosum*) is a perennial crop of the family Solanaceae, dominantly grown by the North and South Americans. It is one of the most important food crops grown worldwide due to its economical and nutritional values (Singh *et al.,* 2005). Irish Potato peel (IPP), a waste by product of potato processing, is a good source of phytochemicals (e.g. flavonoids and terpenes) and nutritional components such as starch, dietary fiber, proteins, amino acids, vitamins (B6, B3, C) and mineral elements, particularly potassium (K), phosphorus (P), calcium (Ca), sodium (Na), magnesium (Mg), Manganese (Mn), iron (Fe) and zinc (Zn) (Nostro *et al*., 2000). Since potato peel is fortified with essential organic matter, it is often used as food preservative, pharmaceutical ingredient, renewable energy and animal feed to promote friendly environment (Gebrechristos *et al*., 2018). Potato peel waste is also a potential source of steroidal alkaloids which are biologically active secondary metabolites which possesses anti-inflammatory, antimicrobial, and anti-carcinogenic properties. Glyco-alkaloids produced by potato peels are resistant to challenges such as bacterial, fungal and insect attacks and pests (Siddique *et al*., 2019).

With attempts to solve the crisis of growing shortage of feed energy and rising cost of conventional feeds, a variety of health-related benefits of agricultural wastes, such as potato peels have also been encountered. For instance, previous studies had shown appreciable result with the use of Potato peels and Sugar beet pulp, such as reduction in fat deposition etc. (Abdel-Hafeez *et al*., 2018). Likewise, potato peel powder showed exceptionally high anti-obesity properties in mice consuming high fat diet (Elkahoui *et al*., 2018).

The utilization of wastes demands urgent attention as the recycling of wastes directly decrease environmental pollution and provide solutions to the current issues by creating novel materials from wastes, such as animal feed. This can be either indirectly in the form of nutrient improvement by microorganisms or directly as diet ingredient for livestock feed production (Ojokoh *et al.* 2020). There is, therefore, need to intensify research about potato peel since it is one of the prominent food wastes that could be used as alternative animal feed due to natural sources of energy and fiber with low levels of protein. The present study shows the analyses of the proximate, mineral, anti-nutritional factors of Irish potato peels, as well as its effects on haemato-biochemical and antioxidant profiles, histological integrity of some internal organs and spermatozoa quality indices in Wistar rats.

Materials and methods

Animals and experimental design

Twenty male Wistar rats (weighing between 100g and 120g) were purchased from the Department of Physiology, University of Ibadan, Nigeria. The animals were kept in metabolic cages at the Animal house of the Department of Veterinary Physiology and Biochemistry, University of Ibadan, and allowed to acclimatize for a period of one week. At the commencement of the experiment, the rats were randomly assigned into two groups (A and B) comprising 10 rats each. Group A served as the control and were fed commercial rat concentrates feed while group B rats were fed with processed Irish potato peel diet. Each rat was given about 25g of feeds per day for 14 days with water *ad libitum*.

Animal management and ethical practices

This research is a nutritional evaluation hence no toxic substances were administered to the rats. The metabolic cages were cleaned daily to remove faeces and urine to prevent ammonia build-up. The rats were handled with utmost care during weighing to avoid trauma. The rats were anaesthetized with Diethyl ether during blood sample collection via the orbital vein to avoid excessive pain. Following euthanasia, carcasses were disposed in appropriate incinerators to avoid pollution and contamination to the environment. An Ethical Approval Certificate was given for this research with Ethical Approval Number: **UI-ACUREC/18/0140.**

Feed collection and preparation

Irish Potato tubers were purchased from a local market in Ibadan, Nigeria and peeled. The tubers were processed into chips for consumption while the peels were adequately sun-dried for a week to remove the moisture content. The peels were then reduced into smaller fragments by milling. The Irish potato peels were measured into wraps of 25g each for daily administration.

Proximate analysis

The Proximate analysis of feed for Crude Protein, Crude Fibre, Crude Fat, Ash

Content, Moisture Content / Dry Matter, Nitrogen Free Extract and Gross Energy) was done according to methods described by AOAC (2000).

Mineral analysis

Sodium (Na) and Potassium (K) contents were determined by flame photometry (Jenway Ltd, Dunmow Essex, UK) and Phosphorus (P) by Vanado-molybdate method (AOAC, 2005). Calcium (Ca), Magnesium (Mg), Iron (Fe) and manganese (Mn) levels were determined after wet-digestion with a mixture of Nitric, Sulphuric and Hydrochloric acids using atomic absorption spectrophotometry (Buck Scientific, East Norwalk, CT, USA).

Quantification of anti-nutritional factors

Trypsin inhibitor activity of the samples was analysed by the method of Liener (1979). The total oxalates were quantified according to the procedure of Fasset (1996). Phytates was determined based on the method of Maga (1983). Tannins was analysed using the method of Dawra *et al*. (1988). Saponin level was quantified according to the procedure of Brunner (1984). Alkaloid level was determined using the procedure of Henry (1973).

Digestibility studies

The housing of the animals individually in metabolic cages allowed for separation of faeces and urine, with each cage equipped with an automatic drinker nipple and a manual feeder. The standard method fully described by Perez *et al*. (1995) was used. The apparent nutrient digestibility coefficients of the diets were determined according to the standard formula:

Apparent Nutrient Digestibility (%) = (NI-NE)/NI ×100, where, "NI" represents Nutrient Intake and "NE" represents the Nutrient excreted.

Haematological and serum biochemical analyses

Packed cell volume, Haemoglobin concentration, Red blood cell count, Platelets count, White blood cells count according to Jain (1986). Alanine aminotransferases, Aspartate aminotransferases, Alkaline phosphatases were determined using Randox kits (Crumlin BT29 4QY, UK) according to manufacturer's instructions.

Oxidative stress and antioxidant markers

Protein concentration of the serum was determined by Biuret method as described by Gornal *et al.* (1949). Glutathione peroxidase (GPx) activity was determined as described by Rotruck *et al.* (1973). Glutathione-S-transferase (GST) was measured by the method of Habig *et al.* (1974) using 1-chloro-2, 4-dinitrobenzene as substrate. Superoxide dismutase (SOD) was determined by measuring the inhibition of auto-oxidation of epinephrine at pH 10.2 as described by Misra and Fridovich (1972). The malondialdehyde (MDA) level measured as described by Varshney and Kale (1990). Lipid peroxidation in µmol MDA formed/mg protein was computed with a molar extinction coefficient of $1.56 \times 10^5\ M^{-1}\ cm^{-1}$. Hydrogen peroxide ($H_2O_2$) generation was estimated as described by Wolff (1994). Reduced glutathione (GSH) concentration was determined according to the method of Beutler *et al.* (1963).

Histopathology

Small portions of the liver, kidney and testes were fixed in 10% formalin (v/v), embedded in paraffin wax, and sections of 5–6 mm thickness were made. These were then stained with hematoxylin and eosin (H&E) for histopathological examination according to the methods described by Drury and Wallington (1976). Thereafter, the sections were examined with light microscope.

Determination of sperm characteristics

Morphological studies

On a clean, warm glass slide, a drop of semen was placed as well as two drops of Wells and Awa stain. The semen and stain were thoroughly mixed together with a smear made on another clean and warm slide. The smear was air-dried and observed using the light microscope starting with low power to high magnification. The presence of abnormal cells out of at least 400 sperm cells from several fields on the slide was counted and their total percentage was estimated appropriately (Hammer, 1970).

Motility

Sperm motility was evaluated microscopically within 2-4 minutes of their isolation from the cauda epididymis and later expressed as percentages (Zemjanis, 1970).

Sperm count

Epididymal sperm count was obtained by mincing the cauda epididymis in distilled water and filtering through a nylon mesh. The spermatozoa were counted by haemocytometer using improved Neubauer chamber (Deep 1/10mm, LABART, Germany) described by Pant and Srivastava (2003).

Sperm live/dead ratio

A drop of semen was placed in 1% eosin and 5% nigrosin in 3% sodium citrate dehydrates solution for the live/dead ratio as described by Wells and Awa (1970).

Statistical analysis

Where applicable, all the values were expressed as the mean±standard deviation. Statistical analysis was carried out using the PRISM software package (version 5.0, GraphPad Software Inc., San Diego CA, USA). The statistical significance was assessed by Student's t-test. Values of probability lower than 5% was considered statistically significant.

Results

Proximate composition of the feed

The proximate composition of the Irish potato peels and concentrate feed is presented in Table 1. The analysis shows that the concentrate feed given to control rats had higher levels of crude protein, energy, fat and ash than the Irish potato peels. However, there were higher contents of fibre, dry matter and nitrogen-free extract in the Irish potato peels compared to the concentrate feed.

Table 1: Proximate analysis of Irish potato peel and concentrate feed

Parameters	Concentrate feed	Irish Potato Peel
% Crude Protein	10.53 ± 0.09^a	4.54 ± 0.06^b
% Crude Fat	2.67 ± 0.01	1.65 ± 0.02
% Crude Fibre	2.77 ± 0.03^b	4.81 ± 0.03^a
% Ash	5.63 ± 0.02^a	3.67 ± 0.01^b
% Moisture	9.57 ± 0.02	9.90 ± 0.02
% Dry Matter	63.62 ± 0.01^b	67.89 ± 0.02^a
% NFE	5.31 ± 0.02^b	7.54 ± 0.04^a
Gross energy (Kcal/g)	4.00 ± 0.002^a	2.92 ± 0.00^b

Values are presented as mean ± standard deviation (STD) (n=5). [a]represents values significantly (p<0.05) higher than corresponding values in the other group; [b]represents values significantly (p< 0.05) lower than corresponding values in the other group.

Mineral content of the feed

The mineral contents of the feed samples (Irish potato peels and concentrate feed) are presented in Table 2. Levels of Mg, Ca, Na, K, Mn, Fe and P were higher in the concentrate-fed rats, compared to those in Irish Potato peels, although Cl^- ions were more abundant in the Irish potato peels.

Table 2: Mineral contents of Irish potato peels and concentrate feed

Parameters	Concentrate feed	Irish Potato Peel
% Magnesium (Mg)	0.16 ± 0.001	0.12 ± 0.001
% Calcium (Ca)	0.14 ± 0.002	0.10 ± 0.004
% Sodium (Na)	0.12 ± 0.001[a]	0.05 ± 0.002[b]
% Potassium (K)	0.27 ± 0.002	0.26 ± 0.003
Manganese (Mn) (mg/kg)	14.00 ± 0.28[a]	8.50 ± 0.14[b]
Iron (Fe) (mg/kg)	22.06 ± 0.02[a]	12.40 ± 0.14[b]
Cl^- (mg/kg)	723.20 ± 0.01[b]	856.5 ± 0.04[a]
% Phosphorus (P)	0.25 ± 0.003	0.21 ± 0.003
% Chloride (Cl)	0.72 ± 0.00001[b]	0.87 ± 0.00004[a]

Values are presented as mean ± standard deviation (STD) (n=5). [a]represents values significantly (p<0.05) higher than corresponding values in the other group; [b]represents values significantly (p<0.05) lower than corresponding values in the other group.

Anti-nutritional factors in the feed

The contents of anti-nutritional factors, including Trypsin Inhibitor, Cyanogenic glycoside (HCN), Phytate, Oxalate, Saponin, Tannin, Alkaloid, Flavonoids, Haemagglutinin in the Irish Potato Peel and Concentrate feed are shown in Table 3. The analysis showed that the concentrate feed contained much higher levels of anti-nutritional factors, including Trypsin inhibitor, Cyanogenic glycosides, Phytates, oxalates and haemagglutinin compared to the Irish potato peels. On the other hand, the potato peels contained higher levels of saponins, alkaloids and flavonoids than those found in the concentrate feed.

Table 3: Anti-nutritional factors in Irish potato peel and concentrate feed

Parameters	Concentrate feed	Irish Potato Peel
Trypsin Inhibitor (mg/g)	2.20 ± 0.04[a]	0.87 ± 0.03[b]
Cyanogenic glycoside (mg/kg)	4.2 ± 0.01[a]	3.25 ± 0.02[b]
% Phytate	0.16 ± 0.002	0.113 ± 0.001
% Oxalate	0.126 ± 0.001[a]	0.09 ± 0.004[b]
% Saponin	0.16 ± 0.002	0.18 ± 0.002
% Tannin	0.002 ± 0.0001	0.002 ± 0.0001
% Alkaloid	0.14 ± 0.002	0.15 ± 0.002
% Flavonoids	-	0.002 ± 0.000007
Haemagglutinin (HU/mg)	11.15 ± 0.02[a]	9.25 ± 0.03[b]

Values are presented as mean ± standard deviation (STD) (n=5). [a]represents values significantly (p< 0.05) higher than corresponding values in the other group; [b]represents values significantly (p<0.05) lower than corresponding values in the other group.

Body weight changes

As presented in Table 4, there was significant (p<0.05) reduction (14%) in the final average body weight of rats fed IPP (Group B). Rats in the control group, however, recorded a significant (p<0.05) increase (30.75%) in their body weights.

Table 4: Weight changes in rats fed Irish potato peel and concentrate feed

	Initial weight (g)	Final weight (g)	% Weight gain/loss
GROUP A	112.25±2.10	143±2.63[a]	30.75
GROUP B	113±2.75	99±1.76[b]	-14

Values are presented as mean ± standard deviation (STD) (n=5). [a]represents values significantly (p<0.05) higher than corresponding values in the other group; [b]represents values significantly (p<0.05) lower than corresponding values in the other group.

Digestibility indices

The percentage digestibility of the proximate components of the control feed and Irish potato peels are shown in Table 5. The result shows that about 40.54% of the crude protein in the control feed was digested and this value was significantly ($p<0.05$) higher than the 15.44% digested from the Irish potato peels. The same trend was observed in the Crude Fat as 55.41% of the control feed digested as against 37.99% from the Irish potato peels. However, the percentage Crude fibre digested from the Irish potato peels was significantly ($p<0.05$) higher than that of the control feed with values of 52.91 to 4.66%, respectively. The digestibility values of the Ash and Gross Energy (Kcal/g) for the control feed was significantly ($p<0.05$) higher than the Irish potato peels with 23.67% compared to 6.41% and 65.41% compared to 52.13%, respectively.

Table 5: Percentage digestibility of proximate components in Irish potato peel and concentrate feed

Parameters	Concentrate feed	Irish Potato peels
% Crude Protein	40.54^{a}	15.44^{b}
% Crude Fat	55.41^{a}	37.99^{b}
% Crude Fibre	4.66^{b}	52.91^{a}
% Ash	23.67^{a}	6.41^{b}
% Dry Matter	86.68^{b}	100^{a}
% NFE	67.43^{b}	100^{a}
GROSS ENERGY (Kcal/G)	65.41^{a}	52.13^{b}

Values are presented as mean ± standard deviation (STD) (n=5). [a]represents values significantly ($p<0.05$) higher than corresponding values in the other group; [b]represents values significantly ($p<0.05$) lower than corresponding values in the other group.

Anti-nutritional factors in the faeces

The anti-nutritional factors in the faeces of the rats fed Irish potato peels and the control feed were also subjected to analysis. The results, as presented in Table 6, shows significantly higher levels of Saponins Alkaloids, Tannins and Trypsin inhibitor were present with low digestibility values of 29.26%, 32.23%, 52.78% and 56.90% in the potato peels. However, Cyanogenic glycosides (84.65%) Phytates (80.09%), Oxalates (86.74%) and Flavonoids (100%) were sufficiently metabolized by the IPP-fed rats. Similar pattern was observed in the control rats however with varying levels of digestibility.

Table 6: Digestibility indices of anti-nutritional factors in Irish potato peel and concentrate feed

Parameters	**Concentrate feed**	**Irish Potato peels**
Trypsin Inhibitor (mg/g)	63.36^{a}	56.90^{b}
Cyanogenic glycoside (mg/kg)	85.35	84.65
% Phytate	79.94	80.09
% Oxalate	86.00	86.74
% Saponin	24.84^{b}	29.36^{a}
% Tannin	47.83^{b}	52.78^{a}
% Alkaloid	17.91^{b}	32.23^{a}
% Flavonoids	-	100.00
Haemagglutinin (HU/mg)	42.16^{b}	54.54^{a}

Values are presented as mean ± standard deviation (STD) (n=5). [a]represents values significa ntly ($p<0.05$) higher than corresponding values in the other group; [b]represents values significantly ($p<0.05$) lower than corresponding values in the other group.

Mineral constituents

The mineral components in the concentrate feed showed significantly higher digestibility compared to the potato peels with Magnesium, Calcium, Sodium, Potassium, Manganese, Iron and Phosphorus all having higher percentage digestibility than the Irish potato peel (20.70 to 4.88%, 24.65 to 15.60%, 61.38 to 7.80%, 36.80 to 27.01%, 40.58 to 14.12%, 47.44 to 16.55% and 55.56 to 37.80%, respectively) (Table 7). However, the percentage digestibility of Chloride in Irish potato peel group was significantly higher than the control (70.2 to 67.99%).

Table 7: Digestibility indices of mineral constituents in Irish potato peel and concentrate feed

Parameters	Concentrate feed	Irish Potato peels
% Mg	20.70[b]	4.88[b]
% Ca	24.65[a]	15.60[b]
% Na	61.38[a]	7.80[b]
% K	36.80[a]	27.01[b]
Mn (mg/kg)	40.58[a]	14.12[b]
Fe (mg/kg)	47.44[a]	16.5[b]
Cl^- (mg/kg)	67.99[b]	70.2[a]
% P	55.56[a]	37.80[b]
% Cl	67.99[b]	70.20[a]

Values are presented as mean ± standard deviation (STD) (n=5). [a]represents values significantly (p<0.05) higher than corresponding values in the other group; [b]represents values significantly (p<0.05) lower tha n corresponding values in the other group.

Haematological parameters

There were no significant differences in the packed cell volume (PCV), Haemoglobin concentration (Hb) and red cell counts (RBC) and platelet count between the rats fed IPP and those fed the concentrate (Table 8a). However, the white cell count (WBC) in the IPP-fed rats was significantly lower than those of the concentrate-fed rats. The lower WBC values was reflected in significantly (p<0.05) lower neutrophil and monocyte differentials (Table 8b).

Table 8a: Haematological parameters in rats fed Irish potato peel and concentrate feed

Parameters	PCV (%)	HB (g/dl)	RBC ($x10^6mm^3$)	WBC ($x10^3mm^3$)	Platelet ($x10^3mm^3$)	MCH (pg)	MCV (fL)	MCHC (g/dL)
GROUP A	42.48±0.74	6.24±0.37	4.7±0.4	14.13±0.15[a]	67.5±3.25	13.28±0.23	91.06±3.11	14.58±1.9
GROUP B	42.92±2.02	6.36±1.19	4.9±0.15	11.98±0.16[b]	67.5±4.84	12.38±5.22	87.59±2.22	14.82±0.38

Values are presented as mean ± standard deviation (STD) (n=5). [a]represents values significantly (p<0.05) higher than corresponding values in the other group; [b]represents values significantly (p<0.05) lower than corresponding values in the other group. Packed Cell Volume (PCV), Haemoglobin (Hb), White blood Cell (WBC), Red Blood Cell (RBC).

Table 8b: White blood cell differentials in rats fed Irish potato peel and concentrate feed

Parameters	Lymphocytes ($x10^3mm^3$)	Neutrophils ($x10^3mm^3$)	Monocytes ($x10^3mm^3$)	Eosinophil ($x10^3mm^3$)
GROUP A	3.89±3.45	1.87±0.83[a]	1.87±0.87[a]	6.50±0.61
GROUP B	4.01±3.97	0.66±0.51[b]	0.66±0.51[b]	6.65±0.81

Values are presented as mean ± standard deviation (STD) (n=5). [a]represents values significantly (p<0.05) higher than corresponding values in the other group; [b]represents values significantly (p<0.05) lower than corresponding values in the other group.

Serum chemistry parameters

As shown in Table 9, there were no significant differences in the activities of Alanine aminotransferase (ALT), Aspartate aminotransferase (AST) and Alkaline phosphatase (ALP) between the IPP- and concentrate-fed rats. However, the results showed significantly lower levels of total protein, albumin and globulin levels in rats fed IPP compared to those fed the concentrate.

Table 9: Serum chemistry parameters in rats fed Irish potato peel and concentrate feed

Parameters	ALT (U/L)	AST (U/L)	ALP (U/L)	Total protein (mg/kg)	Albumin (mg/kg)	Globulin (mg/kg)	BUN (mg/kg)
GROUP A	27.25±1.66	82.5±7.07	116.51±0.56	90±0.73[a]	50±0.50[a]	40±0.23[a]	75±0.43
GROUP B	29.33±3.33	85.5±5.05	116.75±0.84	80±0.78[b]	46±0.15[b]	36±0.63[b]	72±0.55

Values are presented as mean ± standard deviation (STD) (n=5). [a]represents values significantly ($p<0.05$) higher than corresponding values in the other group; [b]represents values significantly ($p<0.05$) lower than corresponding values in the other group. Alanine aminotransferase (ALT), Aspartate aminotransferase (AST), Alkaline phosphatase (ALP), Blood Urea Nitrogen (BUN).

Tissue oxidative stress and antioxidant markers

The content of oxidative stress markers (Hydrogen peroxide, H_2O_2; Malondialdehyde, MDA and Nitric oxide, NO) and antioxidant markers (reduced glutathione, GSH, Glutathione peroxidase, GPx, Superoxide dismutase, SOD and Glutathione S-transferase, GST) in the kidney, liver and testes are presented in Figures 1 and 2, respectively. Rats fed with IPP had generally lower contents of H_2O_2, MDA and NO, with the values significantly lower in the liver and kidneys, when compared with rats fed the concentrate diet (Fig. 1). As shown in Fig. 2, kidney GSH levels and GPx activity were significantly ($p<0.05$) higher in the kidneys of IPP-fed rats than in those of the concentrate-fed rats. Rats in the IPP-fed group also had higher hepatic activities of GPx and SOD, compared to the concentrate-fed group. The activity of GST was, however, unaltered in all the tissues examined.

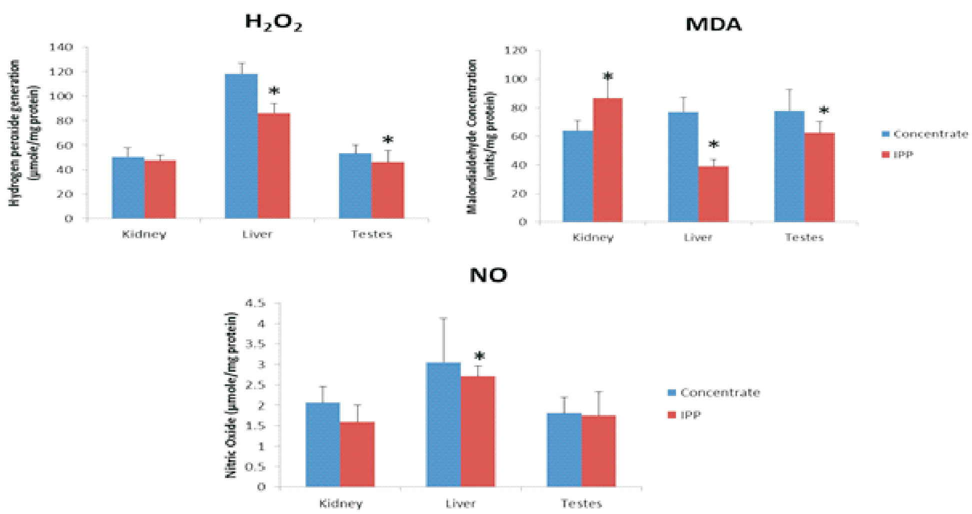

Figure 1: Levels of Hydrogen peroxide, Malondialdehyde and Nitric oxide in the kidneys, Liver and testes of rats fed with Irish potato peels or Concentrate diet.

Values are presented as *Mean±SD of Group A (Control) and Group B (Rats fed with Irish Potato peels); n=5. * indicates significant difference ($p<0.05$) between IPP and concentrate-fed rats.*

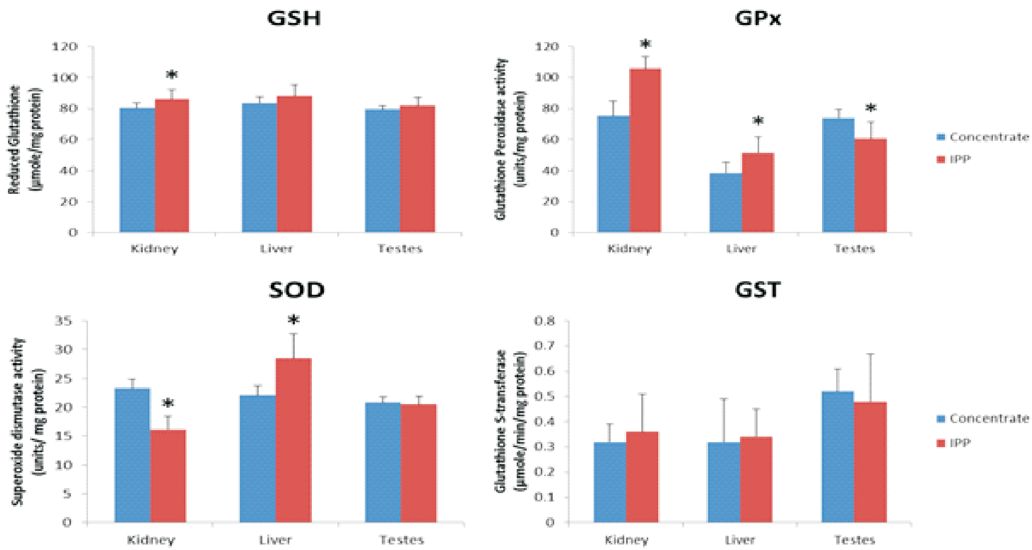

Figure 2: Levels of reduced glutathione (GSH) and activities of Glutathione peroxidase (GPx), superoxide dismutase (SOD) and Glutathione S-transferase (GST) in the kidneys, Liver and testes of rats fed with Irish potato peels or Concentrate diet.
Values are presented as *Mean±SD of Group A (Control) and Group B (Rats fed with Irish Potato peels); n=5. * indicates significant difference (p<0.05) between IPP and concentrate-fed rats.*

Spermatozoa quality parameters
The analysis of spermatozoa quality characteristics in the experiment showed that rats fed IPP recorded significantly ($p<0.05$) higher values for motility, livability and sperm count, compared to the concentrate-fed rats (Table 10).

Table 10: Spermatozoa characteristics in rats fed Irish potato peels and concentrate diet

Sperm parameter	Group A	Group B
% Motility	61.17±2.6[b]	68.33±1.96[a]
% Livability	77.71 ±16.55[b]	81.16± 12.5[a]
Sperm count	4.88± 0.25[a]	5.81± 0.52[a]

Values are presented as mean ± standard deviation (STD) (n=5). [a]represents values significantly (p<0.05) higher than corresponding values in the other group; [b]represents values significantly (p<0.05) lower than corre sponding values in the other group.

Histopathology
Generally, there were no significant lesions observed in the liver, kidneys and testes in all the sections examined for rats fed either IPP or the concentrate diet (Fig. 3), indicating the absence of any significant injuries as a result of components of the feed.

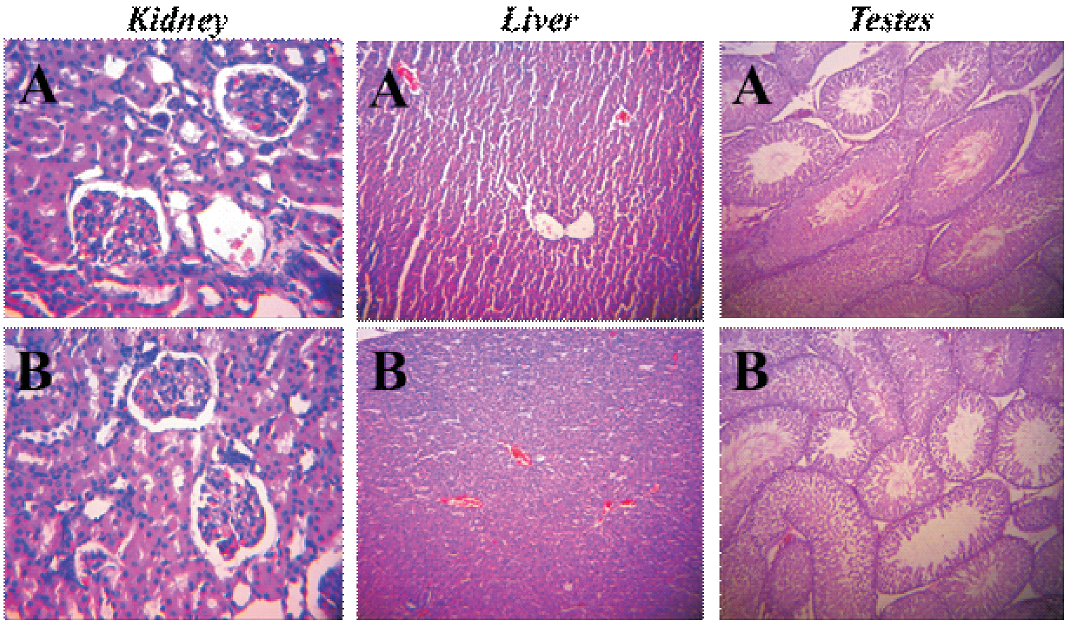

Figure 3: ***Photomicrograph of the Kidneys (H&E; Mag. X400), Liver (H&E; Mag. X100) and testes (H&E; Mag. X200) of rats fed Concentrate feed (A) and Irish Potato peels (B). No lesions were visible in the kidneys, liver and testes.***

Discussion

The rising costs of grains in conventional animal feed have potentiated the search for less-costly alternatives as non-conventional energy and nutrient sources, such as the peels from tubers including potatoes, cassava, etc. (Wadhwa *et al.*, 2013). Although, traditionally regarded as agricultural 'wastes', potato peels have been suggested to be excellent source of nutrient for livestock feed (Chimonyo, 2017) The present report is an attempt to evaluate the nutritional potential and biochemical effects of Irish potato peels as a possible alternative to compounded concentrate feed. The present study showed that IPP contained generally lower contents of various proximate contents, including crude protein, fat, ash and gross energy yield, compared to the concentrate feed. This result of this study is supported by Chimonyo (2017) who also reported that potato peels are good natural sources of energy and crude fibre with low levels of protein. Specifically, low protein levels of feed is indeed desirable in some categories of livestock such as broilers (van Harn *et al.,* 2019), illustrating the potential benefit of protein sources such as IPP. In some other categories of livestock, however, some degree of nutrient fortification of IPP may be required to achieve optimal growth performance. Similarly, low fat and high crude fibre contents of IPP, as observed in the present study, have been proposed as a good combination for the improvement of chemical and physical characteristics of feed (Saed and El-Waseif, 2018). Dietary fibres stimulate normal gastric motility, increases digestibility and prevents constipation. Dietary fibres also have numerous medical benefits such as the lowering blood cholesterol, maintenance of blood sugar level and reduction of body weight (Soetan and Olaiya, 2013).

The results obtained in this study showed that the concentrate feed contained higher levels of the minerals Mg, Ca, Na, K, Mn, Fe and P than the levels found in IPP, although significant differences in the levels of these minerals were only recorded for Na, Mn and Fe. However, chloride levels were much higher in IPP compared to the concentrate. Sodium is an important mineral that assist in the regulation of body fluid and in the maintenance of electric potential in the body tissue, while Iron is required for blood formation and it is important for normal functioning of the central nervous system (Adeyeye and Fagbohun, 2005). It also facilitates the oxidation of carbohydrate, protein and fats. Phosphorus regulates essential biochemical processes like regulation of enzyme activity, formation skeletal structures (bones and teeth) and in neuromuscular irritability (Kalita *et al*. 2007). Interestingly, the results showed that IPP had much lower values of anti-nutritional factors, including Trypsin inhibitor, Cyanogenic glycosides, Phytates, oxalates and haemagglutinin, as compared to the concentrate feed. When present in animal feed, anti-nutritional factors (ANFs) tend to reduce the availability of one or more nutrients either by themselves or via their metabolic products (Yacout, 2016). Contrary to the belief that unconventional feedstuffs generally contain high levels of ANFs (Huisman and Tolman, 2001), the present result shows that IPP indeed contain lower levels of the measured ANFs and thus highlights its profound nutritional potential for incorporation into animal feed. Among ANFs, the compounds most likely associated with adverse effects in animals include protease inhibitors, lectins, tannins, saponins, oxalates and cyanide. For instance, trypsin inhibitors have been associated with hypertrophy and hyperplasia of the pancreas (Ologhobo *et al.* 2003), while alkaloids are known to cause gastrointestinal and neuronal disorders (Tadele, 2015). Phytates form stable complexes with mineral ions like Ca, Fe, Mg and Zn and lower their bioavailability for intestinal absorption (Walter Lopez *et al*. 2002). Tannins form insoluble (inactive complexes) with dietary proteins and thereby reduces their biological value, causing reduced weight gain, reduced palatability and poor feed efficiency (Akande and Fabiyi, 2010). Saponins reduce uptake of certain nutrients (cholesterol) in the gut causing hypercholesterolemia (Umaru *et al*. 2007). It causes haemolysis of red blood cells of rats (Akande and Fabiyi, 2010). Oxalates may form complexes with calcium forming calcium crystals which get deposited as stones and are associated with blockage of renal tubules (Banso and Adeyemo, 2007). The higher content of ANFs in the concentrate feed implies that certain nutrients may be unavailable for absorption in the animals, despite their presence at high levels in the feed. In the *in vivo* experiment, rats fed IPP recorded a significant drop in their body weights during the period of the study. In contrast, the average body weight of rats in the control group which were fed concentrate diet was significantly increased during the 14-day feeding period. In addition to relatively lower levels of major nutrients in IPP, the present data also showed poor digestibility indices for crude protein, fat and gross energy. The digestibility of a feed nutrient measures the degree to which the nutrient is digested and absorbed by the gastrointestinal tract, and is usually expressed as a percentage (Welch, 2011). Overall, it is likely that the reduction in body weights of rats fed IPP was due to its relatively poor digestibility indices. Similar trend of digestibility was also recorded for the mineral constituents of both diets tested in this study. The potential of formulated diets to induce alterations in haematological indices and serum biochemical profiles of animals has been well documented (Chandra *et al*., 2018), and may give indication of the suitability, or otherwise, of diets fed to animals. In the present study, we found no significant differences in the packed cell volume (PCV), haemoglobin (Hb), red blood cell count (RBC) and platelet counts between animals fed IPP and the concentrate diet, suggesting that the feeding of IPP did not result in disturbances to erythrocyte indices that could adversely impact the health of the rats. However, the white blood cell count (WBC) in rats fed IPP was significantly lower than those fed the concentrate diet, and this could be attributed to lower values of neutrophil and monocyte differentials. White blood cells, also called leucocytes, are important mediators of immune responses in living organisms, and low WBC counts have generally been regarded as a stress response (Adesina *et al*., 2017). The reduced WBC counts in IPP-fed rats, as obtained in this study, may therefore, represent a response of the immune system to components of IPP. Alterations in the activities of serum enzymes, such as Aspartate aminotransferase (AST), alanine aminotransferase (ALT) and alkaline phosphatase (ALP) are often utilized as markers of toxicity for the assessment of biochemical and physiological health of vital organs and tissues, such as the liver and heart (Gabriel and George, 2005). It is established that damage to cellular membranes in tissues where these enzymes are normally localized results in their leakage into the bloodstream giving an index of cellular integrity (Coppo *et al.,* 2002). The results indicate that there were no significant differences in the serum activities of ALT, AST and ALP between rats fed IPP and those fed the concentrate diet. This suggests that both feed do not exert noticeable injuries to vital organs such as the liver and heart where the activities of these enzymes are normally predominant. However, there was significantly lower serum protein and albumin levels in rats fed IPP, compared to the concentrate-fed rats. The recorded low serum protein levels may be a direct reflection of low protein content of IPP, as shown by proximate analysis. Low protein levels in the diet might have led to the deficiency of amino acids necessary for the synthesis of proteins such as albumin in the liver (Jee *et al*., 2005). In further evaluation of the biochemical effects of IPP and the concentrate diet, we evaluated the status of some oxidative stress and antioxidant parameters in the liver, kidneys and testes of the rats. It was observed that rats fed IPP exhibited lower levels of hepatic H_2O_2, MDA and NO, compared to the control rats fed concentrate feed. In addition, IPP-fed rats also showed lower levels of H_2O_2 and MDA in the testes, compared to the concentrate-fed rats.

Furthermore, feeding of rats with IPP produced better antioxidant effects, with the rats in this group showing higher levels of GSH and greater activities of GPx and SOD in the liver. Moreover, higher values of renal GSH and GPx, as well as testicular GPx were recorded for IPP-fed compared to the control rats. The above data provides indication for a more favorable antioxidant status when rats were fed with IPP compared to the concentrate diet. Previous research on sweet potato parts fed to albino rats has indicated that the highest antioxidant activity resides in the peels, in comparison with other parts (Althawab *et al.,* 2019). This was attributed to the content of bioactive compounds such as Flavonoids and other polyphenolic compounds in the peels. To our knowledge, the present study shows the significantly higher antioxidant potential of Irish potato peels compared to conventional formulated feed, and we suggest that such potential may be utilized to combat oxidative stress conditions in animals. The histopathological examination of the liver, kidneys and testes showed no distinct lesions in all the sectioned organs suggesting that feeding Irish potato peels may not have deleterious effect on major internal organs. It should be pointed out that despite the potential nutritional benefits highlighted in this study, IPP contained some important nutrients at levels that may require supplementation, fortification or some other means of improving its nutritional potential in order to meet the nutritional requirements of different categories of animals. For instance, Ojokoh *et al.* (2020) suggested that fermentation may be a useful technique for the improvement of crude protein levels, as well as reduction of levels of anti-nutrients in Irish potato peels.

Conclusions

The results of the present study revealed important data on the potential of Irish potato peels as a low-cost alternative source of nutrients and minerals with relatively lower content of anti-nutrients, for possible inclusion in animal diets. However, despite the obvious benefits of feeding IPP to animals, its utilization as a sole diet may not effectively meet nutritional requirements of animals. Therefore, strategies for improving, concentrating and supplementing the peels must be considered to achieve maximum benefits.

References

Abdel-Hafeez, H. M., Saleh, E. S. E., Tawfeek, S. S., Youssef, I. M. I. and Abdel-Daim, A. S. A. 2018. Utilization of Potato Peels and Sugar Beet Pulp with and Without Enzyme Supplementation in Broiler Chicken Diets: Effects on Performance, Serum Biochemical Indices and Carcass Traits. *Journal of Animal Physiology and Animal Nutrition (Berl)*, 102(1): 56-66 doi: 10.1111/jpn.12656.

Adesina, S. A., Falaye, A. E. and Ajani, E. K. 2017. Evaluation of haematological and serum biochemical changes in *clarias gariepinus* juveniles fed graded dietary levels of boiled sunflower (*helianthus annuus*) seed meal replacing soybean meal. *Ife Journal of Science,* 19(1): 51-68.

Adeyeye, E. I. and Fagbohun, E. D. 2007. Proximate, Mineral and Phytate profiles of some selected spices found in Nigeria. *Pakistan Journal of Science and Industrial Research*, 48(1): 14-22.

Akande K. E. and Fabiyi, E. F. 2010. Effect of Processing Methods on Some Anti-nutritional Factors in Legume Seeds for Poultry Feeding. *International Journal of Poultry Science,* 9(10).

Althawab, S. A., Mousa, H. M., Elzahar, K. and Mostafa, A. A. 2019. Protective Effect of Sweet Potato Peel against Oxidative Stress in Hyperlipidemic Albino Rats. *Food and Nutrition Sciences,* 10(5): 503-516.

AOAC 2000. Association of Official Analytical Chemists. Official Methods of Analysis, 17th edition. Washington, DC.

AOAC 2005. Official Methods of Analysis of AOAC International. Maryland, USA.

Banso, A. and Adeyemo, S. O. 2007. Evaluation of Antimicrobial Properties of Tannins Isolated from Dichrostachys cinereaa. ***African Journal of Biotechnology,*** **6: 1785-1787. https://doi.org/10.5897/AJB2007.000-2262**

Beutler, E. O., Duron, B. and Kelly M. 1963. Improved method for the determination of blood glutathione. *Journal of Laboratory and Clinical Medicine,*

Brunner, J. H. 1984. Direct spectrophotometric determination of saponin. *Analytical Chemistry,* 42: 1752-1754.

Chandra, H. K., Mishra, G., Sahu, N.,

Nirala, S. and Bhadauria, M. 2018. Effect of rutin against high-fat diet and alcohol-induced alterations in hematological variables of rats. *Asian Journal of Pharmaceutical and Clinical Research*, 11(11): 186.

Chimonyo, M. 2017. A review of the utility of potato by-products as a feed resource for small-holder pig production. *Animal Feed Science and Technology*, **227**: 107–117.

Coppo, J. A., Mussart, N. B. and Fioranelli, S. A. 2002. Physiological variations of enzymatic activities in the blood of Bullfrog, *Ranacatesbeina (Shaw, 1802). Veterinary Reviews, 12 (13): 22–27.*

Dawra, R. K., Makkar, H. S. P. and Singh B. 1988. Protein binding capacity of microquantities of Tannins. *Analytical Biochemistry*, 170: 50-53.

Drury, R.A. and Wallington, E.A. 1976. Carlton's Histopathological Techniques. 4th ed. London: Oxford University Press; 139–142.

Elkahoui, S., Bartley, G. E., Yokoyama, W. H. and Friedman, M. 2018. Dietary Supplementation of Potato Peel Powders Prepared from Conventional and Organic Russet and Non-organic Gold and Red Potatoes Reduces Weight Gain in Mice on a High-Fat Diet. *Journal of Agricultural and Food Chemistry*, 66(24):6064-6072. doi: 10.1021/acs.jafc.8b01987.

Fasset, D. W. 1996. Oxalates. In: Toxicants occurring naturally in foods. National Academy of Science Research Council, Washington D.C, U.S.A

Gabriel, U. U. and George, A. O. I. 2005. Plasma enzymes in *Clarias gariepinus* exposed to chronic levels of roundup (glyphosate). *Environmental Ecology,* 23 (2): 271–276.

Gebrechristos, H. Y. and Chen, W. 2018. Utilization of potato peel as eco-friendly products: A review. *Food Science and Nutrition,* 1–5.

Gornal, A. G., Bardawill, J. C. and David, M. M. 1949. Determination of serum proteins by means of Biuret reaction. *Journal of Biological Chemistry,* 177: 751–766.

Habig, W. H., Pabst, M. J. and Jacoby, W. B. 1974. Glutathione-S-transferase activity: the enzymic step in mercapturic acid formation. *Journal of Biological Chemistry*, 249: 30–139.

Hammer, C. E. 1970. The Semen. In: Hafez ESE. Reprodcution and Breeding Techniques for Laboratory Animals. Philadelphia: Lea and Febiger; 16-22.

Henry, T. A. 1973. Organic Analysis of Alkaloids. 6:163-187

Huisman, J. and Tolman, G. H. 2001. Anti-nutritional factors in the plant proteins of diets for non-ruminants. *Recent developments in pig nutrition*. Netherlands; 3:261–291.

Jain, N. C. 1986. Schalm's Veterinary Hematology Lea and Febiger, pp. 276-282.

Jee, L. H., Masroor, F. and Kang, J. 2005. Responses of Cypermethrin-induced stress in haematological parameters of Korean rockfish, *Sebastes schegeli*. *Aquaculture Research* 36: 898-905.

Kalita, P., Mukhopadhyay, P. K. and Mukherjee, A. K. 2007. Evaluation of the nutritional quality of four unexplored aquatic weeds from North East India for the formulation of cost-effective fish feeds. *Food Chemistry,* 103: 204-209.

Liener, I. E. 1979. Determination of antitryptic activity of soybean. *Journal of Science and Agriculture,* 16: 602-609.

Maga, J. A. 1983. Phytate: Its chemistry, occurrence, food interaction, nutritional significance and methods of analysis. *Journal of Agriculture and Food Chemistry*, 30: 1-9.

Misra, H. P. and Fridovich, I. 1972. The role of superoxide anion in the autooxidation of epinephrine and a simple assay for superoxide dismutase. *Journal of Biological Chemistry,* 247: 3170–3175.

Nostro, A., Germanò, M. P., D'angelo, V., Marino, A., Cannatelli, M. A., Germano, M. and D'angelo, V. 2000. Extraction methods and bioautography for evaluation of medicinal plant antimicrobial activity. *Letters in Applied Microbiology*, 30(5): 379–384. https://doi.org/10.1046/j.1472-765x.2000.00731.x

Ojebiyi, O. O., Oladunjoye, I. O. and Eso, I. R. 2010. The grain replacement value of sun-dried cassava (Manihot esculenta crantz) leaf + peel meal with or without DL-methionine supplementation on performance of rabbit bucks in the derived savannah zone of Nigeria, *Agricultura Tropica et Subtropica,* 43(4): 291–290.

Ojokoh, A. O., Kassim, A. and Ayeni, O. H. 2020. Changes in Proximate and Anti-nutrient Contents of Irish Potato Peels Fermented with *Penicillium chrysogenum* and *Bacillus subtilis*. *South Asian Journal of Research in Microbiology*. 6(1): https://doi.org/10.9734/sajrm/2020/v6i130141.

Ologhobo, A., Mosenthin, R. and Alaka, O. O. 2003. Histological alterations in the internal organs of growing chicks from feeding raw jackbean or limabean seeds. *Veterinary and Human Toxicology,* 45(1): 10-13

Pant. N. and Srivastava, S. P. 2003. Testicular and spermatotoxic effects of quinalphos in rats. *Journal of Applied Toxicology,* 23: 271–274.

Perez, J. M., Lebas, F., Gidenne, T., Maertens, L., Xiccato, G., Parigi-Bini, R., Dalle Zotte, A., Cossu, M. E., Carazzolo, A., Villamide, M. J., Carabaño, R., Fraga, M. J., Ramos, M. A., Cervera, C., Blas, E., Fernández, J., Cunha, L. F. E. and Freire, J. B. 1995. European reference method for *in vivo* determination of diet digestibility in rabbits. *World Rabbit Science,* 3: 41–43.

Rotruck, J. T., Pope, A. L., Ganther, H. E. *et al*, 1973. Selenium: biochemical role as a component of glutathione peroxidase. *Science,* 179: 588–590.

Saed, B. and El-Waseif. 2018. Effect of dietary fiber in potato peels powder addition as fat replacer on quality characteristics and energy value of beef meatballs. *Journal of Biology, Chemistry and Environmental Sciences*, 13(1): 145-160.

Siddique, M. A. B. and Brunton, N. 2019. Food Glycoalkaloids: Distribution, Structure, Cytotoxicity, Extraction, and Biological Activity. DOI: 10.5772/intechopen.82780.

Singh, N., Kamath, V. and Rajini, P. S. 2005. Attenuation of hyperglycemia and associated biochemical parameters in STZ-induced diabetic rats by dietary supplementation of potato peel powder. *Clinica Chimica Acta* 353: 165 – 175.

Soetan, K. O. and Olaiya, C. O. 2013. Summarizing Evidence Based Information on the Medical Importance of Dietary Fibre. *Annals of Food Science and Technology* 14(2): 393-399.

Tadele, Y. 2015. Important anti-nutritional substances and inherent toxicants of feeds. Food Science and Quality Management, 36: 40-47.

Uche, C. O. Umar, H. S. Girei, A. A. 2020. Assessing the profitability and constraints to Irish potato production in Plateau State, Nigeria. International Journal of Innovative Research and Advanced Studies 7(5): 13-20

Ugonna C.U, Jolaoso M. O, Onwualu A. P. 2013. A technical appraisal of potato value chain in Nigeria. International Research Journal of Agricultural Science and Soil Science 3(8): 291-301,

Umaru, H. A., Adamu, R., Dahiru, D. and Nadro, M. S. 2007. Levels of anti-nutritional factors in some wild edible fruits of Northern Nigeria. *African Journal of Biotechnology*, 6 (16): 1935-1938.

van Harn, J., Dijkslag, M. A. and van Krimpen, M. M. 2019. Effects of low protein diets supplemented with free amino acids on growth performance, slaughter yield, litter quality, and foot pad lesions of male broilers. *Poultry Science* 98(10).

Varshney, R. and Kale, R. K. 1990. Effect of calmodulin antagonists on radiation induced lipid peroxidation in microsomes. *International Journal of Biology,* 158: 733–741.

Wadhwa, M., Bakshi, M. P. S. and Makkar, H. P. S. 2013. *Utilization of fruit and vegetable wastes as livestock feed and as substrates for generation of other value-added products*. Bangkok: Food and Agriculture organization of the United Nations regional office for Asia and the Pacific.

Walter Lopez, H., Leenhardt, F., Coudray, C. and Remesy, C. 2002. Minerals and phytic acid interactions: is it a real problem for human nutrition? *International Journal of Food Science and Technology,* 37(7): 727-739.

Welch, R. W. 2011. Nutrient Composition and Nutritional Quality of Oats and Comparisons with Other Cereals. In: Oats (Second Edition), American Associate of Cereal Chemists International, Pages 95-107.

Wells, M. E. and Awa, O. A. 1970. New technique for assessing acrosomal characteristics of spermatozoa. *Journal of Dairy Science,* 53: 227.

Wolff, S. F. 1994. Ferrous ion oxidation in the presence of ferric ion indicator xylenol Orange for measurement of hydrogen peroxides. *Methods in Enzymology,* 233: 182–189.

Yacout, M. H. M. 2016. Anti-nutritional factors & its roles in animal nutrition. *Journal of Dairy, Veterinary and Animal Research,* 4(1): 237-239. DOI: 10.15406/jdvar.2016.04.00107

Zemjanis, R. 1970. Collection and evaluation of semen. In: Diagnostic and Therapeutic Technique in Animal Reproduction, 2nd edn. Zemjanis R (ed.). The William and Wilkins Company, Waverly Press Inc., Baltimore, MD, pp 139–153.

Received: 10th May, 2021
Accepted: 15th August, 2021