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Research Article
A Smallholder Poultry Feed App: Development and Field Test

[1]O.A. Oyewale, [2]O.O. Ojebiyi, [1]F.A. Adedeji, [1]O. Bamidele and [1]E.B. Sonaiya

[1]African Chicken Genetic Gains-Nigeria, Department of Animal Sciences, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria
[2]Department of Animal Nutrition and Biotechnology, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria

Abstract

Background and Objective: The African Chicken Genetic Gain-Nigeria (ACGG-NG) project members decided to develop a software application to formulate feed rations (feed app) because the available (foreign) feed apps were either too complex for small holders to operate or the feed libraries in such apps could not be edited to include local feed ingredients. The web version of the app is available at http://acggng.com.ng/, whereas the Windows, iOS and Android versions are available at the respective app stores. **Materials and Methods:** Locally-available feed resources in the project states were compiled into a feed library. The ACGG-NG app formulates rations for growers and layers using 50% of their crude protein requirements. The feed formulations are computed via a Pearson square ration formulation procedure that is enhanced by machine learning. A 10-week feeding trial was conducted involving 24 rural households where scavenging birds received app-formulated supplementation (ScAS) and were compared with scavenging birds that received farmer-formulated supplementation (ScFS) or no supplementation (ScNS) as well as a control group of confined birds that were fed proprietary diets (CPD). **Results:** The app is interactive and offers a way to formulate lower target quantities of the supplements when the available quantity of an ingredient is insufficient. The average daily gain of the ScAS growers was 49, 121 and 510% of that of the CPD, ScFS and ScNS growers, respectively. **Conclusion:** The feedapp allowed the use of locally-available feed resources to generate supplementary diets and the app-formulated supplementary diets resulted in enhanced growth in scavenging chickens.

Key words: Feed app, grower chickens, local feed resources, rural households, scavenging birds, small holder poultry

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Corresponding Author: O.A. Oyewale, African Chicken Genetic Gains-Nigeria, Department of Animal Sciences, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Smallholder poultry (SP) is described as a flock of fewer than 100 birds (of unimproved or improved breed) that are raised in either extensive or intensive farming systems[1]. SP make important contributions to the livelihoods of the rural poor[2,3]. Scavenging is widely utilised in SP production; in the scavenging system, birds can quickly develop nutrient deficiencies as most of the materials that are available for scavenging (the scavengeable feed resource base, or SFRB) contain high levels of crude fibre[4]. Roberts and Gunaratne[5] have attributed a major part of the poor performance of scavenging systems to the birds having poor SFRBs. The total SFRB includes: termites, snails, worms, insects, spare grains from sowing, harvesting and processing, grass seeds, fodder tree leaves, waterplants and kitchen left-overs. Seasonal fluctuations in the SFRB occur due to periods where the farmland is fallow or of flooding, cultivation, harvesting and processing. In Nigeria, the SFRB that is available daily to a growing chicken contains less than 2 g of crude protein (CP)[6]. Supplementing the SFRB with locally-available feed resources (LAFR) should improve the overall quality of a flock's nutrition and reduce mortality. SP farmers could formulate such supplementary diets with feed formulation software (apps) on mobile phones[7].

During a 5 years (2015-2019) period of field testing of six dual-purpose chicken breeds among 2100 farmers spread across five agro-ecological zones in Nigeria (the Fresh-water Swamp, the Mangrove Swamp, the Northern Guinea Savanna, the Southern Guinea Savanna and the Sudan Savanna), the African Chicken Genetic Gains project in Nigeria (ACGG-NG) decided to develop a feed app for scavenging birds because the poultry feed apps available at that time were unsuitable. Usually, the available poultry feed apps had a feed library that could not be updated with LAFR. The ACGG-NG app formulates supplementary rations for scavenging grower and layer chickens based on the LAFR. This study reported the development of the ACGG-NG Smallholder Poultry Feed App and the results of its field test with the scavenging chickens of SP farmers.

MATERIALS AND METHODS

Development of a library of locally-available feed resources (LAFR): In 2016, a LAFR library was developed from a literature search with cross-referencing and standardisation of the names of individual ingredients. In 2017, the LAFR library was supplemented by the collection of samples from 60 villages located in five states of Nigeria and different agro-ecological zones: Kebbi State (Sudan Savanna) in the north-west region; Kwara State (Southern Guinea Savanna) and Nasarawa State (Derived Savanna) in the middle belt region and Imo State (Humid Forest) and Rivers State (Forest Lowlands and Mangrove Swamp) in the south-east region (Fig. 1). The collected samples were subjected to proximate analyses. Out of the 153 LAFR that were initially identified, 96 ingredients were used in the development of the feed formulation app due to their relevance and availability [energy sources (43), plant protein sources (19), animal protein sources (9), high fibre/industrial by-products sources (19) and minerals sources (6), Table 1].

Development of the smallholder poultry feed app: The app was developed between January 2017 to June 2018 at Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria. The web version was developed using the Hypertext Preprocessor (PHP) scripting language, whereas the mobile versions were developed using the Ionic Framework, a cross-platform app development environment that allows an app to be deployed across multiple platforms (Android, iOS and Windows). The Pearson square feed formulation method was selected for the diet formulation because, unlike, e.g., linear programming, the Pearson square method does not require the user to specify the prices of the ingredients. Farmers produced the ingredients and did not need to purchase them; hence, the price was not an issue. Machine learning was incorporated into the framework and operation of the app so that it could run iterations and make intelligent decisions during the feed formulation process. Using 2-4 ingredients, the app formulates diets that meet 50% of the CP requirements of growers (i.e., 8%) and layers (i.e., 8.5%). The app optimises the formulated diet by using ingredients with lower amounts of CP before using those with higher amounts of CP. To enable the app to utilise the Pearson square method, at least one specified ingredient must have a CP content that is lower than 8% and another ingredient must have a CP content greater than 8% (or 8.5%). If all the ingredients have CP contents greater than 8%, a diet cannot be formulated.

Figure 2 is a schematic diagram that shows how the app works. The user provides the following inputs to the app: the available ingredients and their respective quantities, the target quantity to be formulated and the class of bird for which a diet is to be formulated. The app executes the following steps:

1. Check the CP values of the specified ingredients from the LAFR Library and group the specified ingredients based on their CP contents

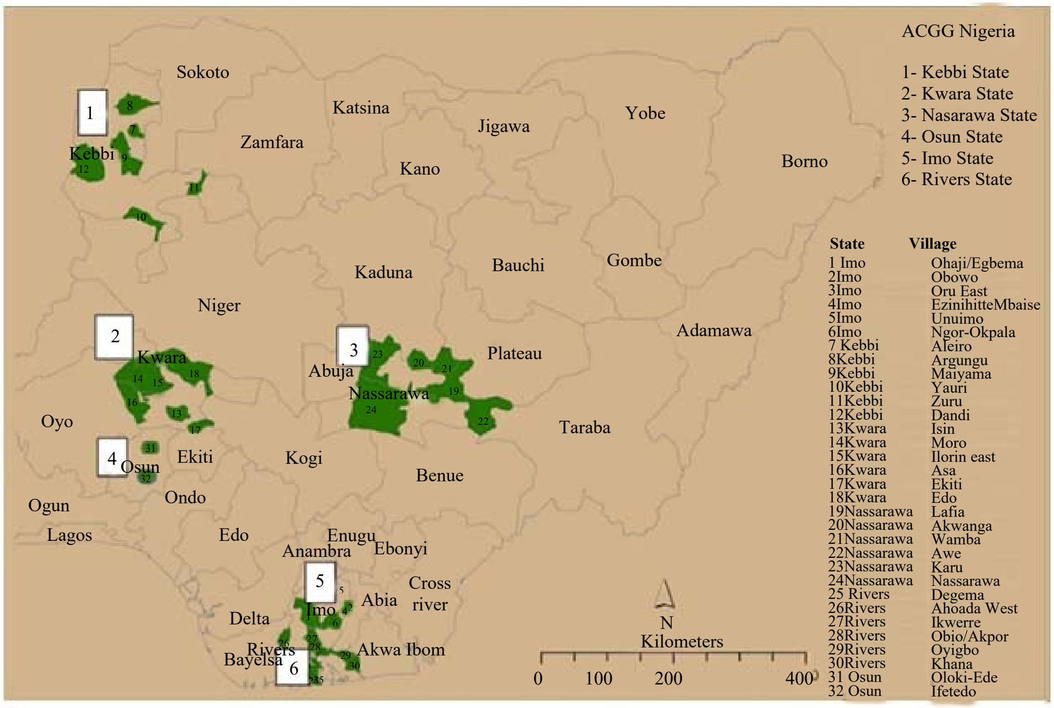

Fig. 1: Locations in Nigeria for local feed resource sample collection and field testing of the smallholder poultry feed application (the App)-formulated supplementary feed

2. Check to ensure that at least one of the specified ingredients belongs to each of the energy and protein sources. The app will return an error message if there is no ingredient in either the energy or the protein group; the app will proceed to the next step if both groups have at least one ingredient that satisfies this requirement
3. Run the Pearson square method
4. Check if the available quantities of ingredients would be sufficient for what is required for the formulation. If all the ingredients are available in sufficient quantities, the app will calculate the nutrient content of the formulated diet and show the result. If the quantity of at least one ingredient is insufficient, the app will reallocate the proportions for the energy and protein groups
5. Iterate steps 3-4 for all possible proportions. If at least one ingredient is insufficient for any iteration, the app will offer to reduce the target quantity to a value for which all the available ingredients are sufficient. If the user accepts the offer, the app will make a formulation for the nearest whole-target quantity for which all the available ingredients are in sufficient quantities and show the result. If the user rejects the offer, the app will show the result based on the user-specified target quantity and indicate the additional quantity of the insufficient ingredients that should be added to the formulation

Field test of the app-formulated diet: Field tests were conducted, from October 2017 to October 2018, in two villages (Ifetedo and Oloki-Ede) in Osun State (Fig. 1).

Determination of LAFR in the test villages: A questionnaire was administered in December 2017 to 30 SP farmers in each village (60 farmers total) to obtain background information on the two study areas. Using this information, in January 2018, a focus group discussion (FGD) was carried out on the feed resources that are available and consumed by the scavenging chickens at different times of the year. A total of 24 farmers (12 from each village) were selected for the supplementation trials; most of these farmers were women who were responsible for the daily management of the chickens. Samples of the identified feed resources were collected from the selected farmers during the focus group discussion.

Quantitative assessment of scavenged feed from chicken crop content: A quantitative assessment of the scavenged feed found in the chickens' crops was carried out between July to October 2018. A total of 48 scavenging growing chickens, aged 6-16 weeks, were used to determine the types and compositions of the consumed diets. The chickens were directly collected from the farmers. Chickens were weighed

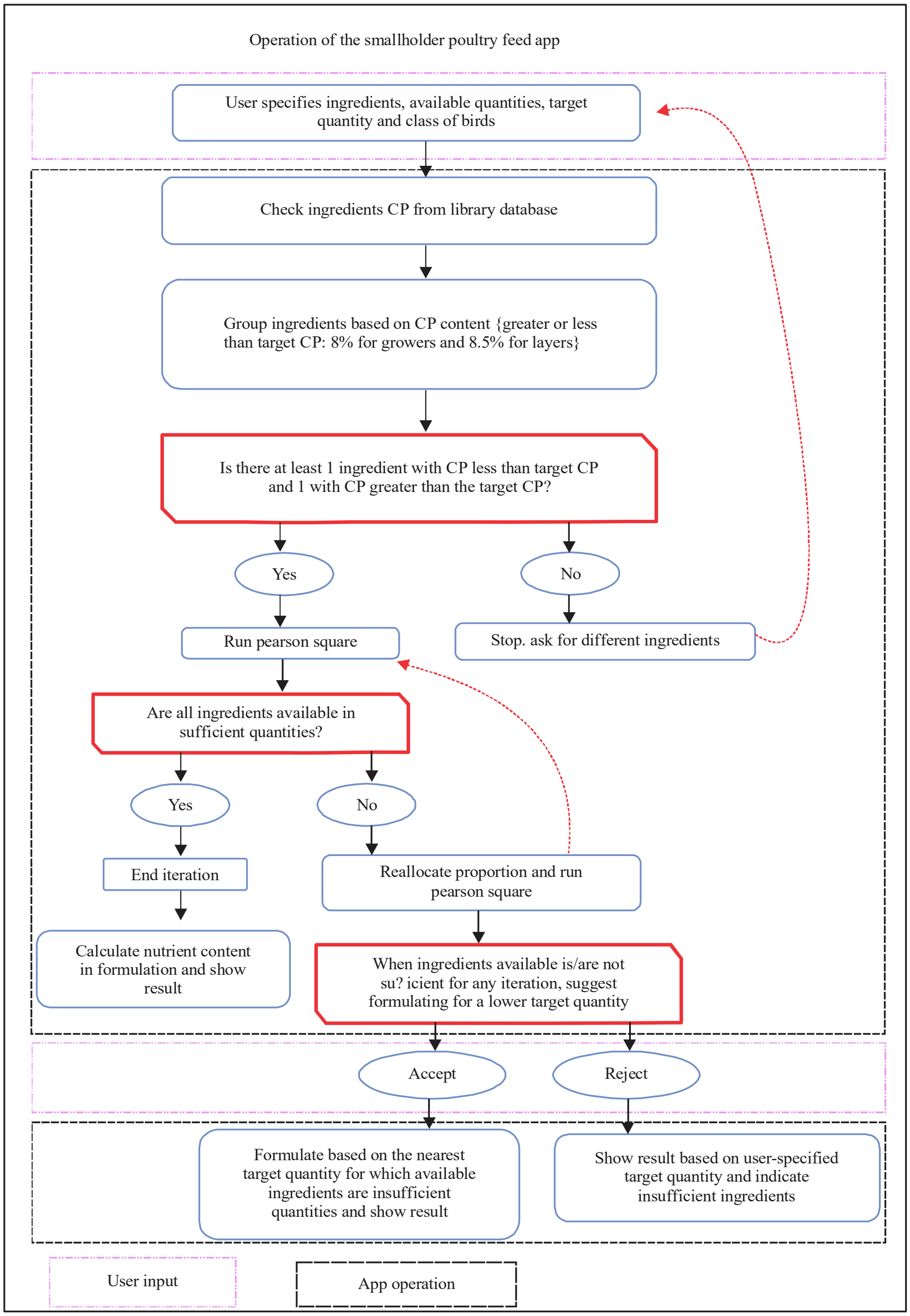

Fig. 2: Schematic diagram showing the operation of the app

before slaughter; the crops were removed and packed in cool boxes containing ice packs. Crop samples were taken to the laboratory where they were frozen at -30°C. Later, the frozen crops were opened up immediately after thawing in air. The ingested feed materials were identified visually using a hand lens and physically separated into different individual feed components. The LAFR samples obtained from the selected farmers and the crop contents of the scavenging grower chickens were analysed for the proximate feed composition, according to previously published methods[8].

Performance of grower birds fed experimental diets: A total of 192 Noiler (a locally developed breed) female growers were given to 24 households and allotted in a randomised complete block design into four treatments: (1) Confined in a cage and fed a proprietary diet (CPD), which served as a control group, (2) Scavenging and receiving the farmer's usual supplementation of grains and leftovers (ScFS), (3) Scavenging and receiving app-formulated supplementation (ScAS) and (4) Scavenging without any supplementation (ScNS). The performance of the birds was monitored for 10 weeks. Data on the birds' initial body weights, daily feed intake and weight gain were collected. The average daily gain and feed conversion ratio values were calculated. Data were analysed using one-way analysis of variance (ANOVA) followed by Duncan's Multiple-Range (DMR) test using the SAS[9].

RESULTS

The names and nutrient contents of the 96 LAFR collected from the literature and the samples collected from the five agro-ecological zones of Nigeria are presented in Table 1a-e. The Smallholder Poultry Feed App (Fig. 3) is available free of cost as a web app and as a mobile app. The web app is accessible at www.acggng.com.ng, whereas the

Table 1a: Energy feed resources for smallholder poultry production

Feed Ingredients	Dry matter (%)	Crude protein (%)	Ether extract (%)	Crude fibre (%)	ME (kcal kg^{-1}) (%)	Calcium (%)	Phosphorus (%)
Acha (grain)	86.67	9.71	1.26	4.48	3511.00	0.28	0.13
Cassava peel meal	87.59	5.33	1.81	14.23	2807.00	0.65	0.25
Cassava flour	89.42	3.10	0.99	3.73	3090.00	0.16	0.37
Cassava leaf meal	92.06	23.79	6.83	17.70	2856.00	1.24	0.60
Cassava grits (gaari)	86.47	1.20	0.38	2.31	3367.00	0.20	0.03
Cassava starch	90.00	2.00	1.00	2.00	2693.00	-	0.01
Cocoyam, tuber	35.60	6.30	0.72	2.40	3604.00	-	-
Sorghum (guinea corn), white	90.00	8.00	3.00	5.00	3300.00	0.04	0.32
Sorghum (guinea corn), red	90.00	8.00	3.00	5.00	3300.00	0.04	0.32
Maize, white	89.10	7.87	5.00	2.60	3245.00	0.02	0.27
Maize, yellow	89.60	8.80	4.80	1.90	3333.00	0.02	0.27
Millet	90.00	12.00	4.20	1.80	3440.00	0.05	0.30
Palm oil	-	-	98.90	-	7710.00	6.00	-
Rice grain, rough	89.00	7.30	1.70	10.00	2940.00	0.04	0.26
Rice grain, polished, broken	89.00	8.50	0.60	0.20	3472.00	0.32	0.34
Rice grain, polished, parboiled	89.00	7.20	0.30	0.20	3482.00	0.13	0.16
Refined soya oil	1.00	-	-	-	7800.00	-	-
Raw soya oil	-	-	-	-	8370.00	-	-
Sweet potato tuber (unpeeled)	94.25	2.76	1.87	1.20	0.60	0.02	0.03
Sweet potato tuber (peeled)	40.00	5.80	0.54	1.20	3596.00	-	-
Wheat ,hard, grain	88.00	13.50	1.90	3.00	3035.00	0.05	0.41
Wheat, soft, grain	86.00	11.80	1.70	2.80	3190.00	0.05	0.30
Water yam, (unpeeled)	25.40	8.20	0.90	2.60	3248.00	-	-
Water yam (peels only)	25.87	11.73	1.01	6.56	3009.00	0.38	0.10
Yellow yam (unpeeled)	22.40	6.30	0.40	2.40	3315.00	-	-
Yellow yam (peeled)	16.10	5.44	0.17	0.77	3387.00	5.19	0.13
Yellow yam (peels only)	21.70	7.42	0.65	7.61	3017.00	1.36	0.13
Ripe pawpaw seeds	96.00	27.40	0.40	27.28	1308.00	0.59	0.26
Water leaf seeds	90.00	18.60	5.00	20.60	1367.00	-	-
Ripe pawpaw fruit (peeled)	94.00	6.55	9.00	6.00	3396.00	0.16	0.07
Ripe plantain fruit	95.00	4.12	0.65	0.05	1005.00	0.10	0.34
Toasted groundnut testa	99.00	18.98	10.00	10.00	912.00	-	-
Soybean testa	90.00	16.63	4.00	25.43	2096.00	0.84	0.78
Cowpea testa	95.75	16.97	2.65	20.35	1005.00	2.06	0.31
Orange pulp	89.48	-	6.78	9.45	1049.00	-	-
Melon fruit pulp	93.50	8.48	4.17	31.06	1148.00	-	-
Orange peelings	85.27	6.80	12.79	8.48	-	-	-
Plantain peels	91.29	14.03	5.74	4.72	1367.00	0.10	0.34
Bitter leaves	89.17	22.80	11.35	11.35	2947.00	-	-
Yam flour sieviates	95.00	3.53	1.00	5.00	2115.00	-	-
Palm oil sludge	91.00	9.00	31.50	12.90	5680.00	-	-
Evaporated palm oil sludge	90.90	4.30	53.20	7.50	4900.00	-	-
Maize starch residue	89.90	14.70	3.80	5.70	3305.00	-	-

Table 1b: Plant protein feed resources for smallholder poultry production

Feed ingredients	Dry matter (%)	Crude protein (%)	Ether extract (%)	Crude fibre (%)	Total ash (%)	ME (kcal kg^{-1}) (%)	Calcium (%)	Phosphorus (%)
African locust bean seed	94.33	30.38	20.30	8.82	5.38	2370	0.37	0.28
African locust bean seed and pod	91.88	19.28	10.60	11.15	6.42	2561	0.28	0.28
African locust bean whole fruit	92.90	12.71	6.75	18.03	6.21	2202	0.40	0.28
Almond kernel	94.06	29.65	36.81	2.67	-	4598	0.50	0.68
Bambara groundnut (decorticated)	92.10	21.14	6.54	5.08	3.78	2661	0.90	0.76
Bambara groundnut (undecorticated)	95.18	17.58	5.26	13.66	5.24	2574	0.90	0.76
Brewer's yeast	90.30	43.10	0.30	6.60	5.30	3049	0.13	1.56
Cashew nut (unextracted)	-	21.18	48.09	0.68	3.30	5494	0.03	0.88
Cashew nut (extracted)	-	36.04	7.44	1.23	5.10	3419	0.06	1.64
Cotton seed, whole seeds with lint	92.00	23.00	19.00	26.00	-	19	0.19	0.16
Full fat soya roasted/toasted	92.00	37.00	18.00	5.50	-	3100	0.20	0.50
Groundnut cake	90.00	40.00	6.00	8.00	-	2640	0.20	0.20
Groundnut meal	90.00	42.00	3.00	8.00	-	2550	0.20	0.20
Pigeon pea	94.70	23.77	1.11	7.49	5.24	3064	1.29	2.80
Roselle seed	88.00	29.00	6.00	17.00	-	2500	0.45	0.20
Sesame seed	94.00	42.00	7.00	6.50	-	2255	2.00	1.30
Sunflower seed	93.00	41.00	7.60	21.00	-	2310	0.43	1.00
Water melon seed (unshelled)	88.00	24.36	35.36	31.63	4.15	1086	0.07	0.31
Water melon seed (shelled)	91.92	34.48	46.74	8.24	6.17	3147	0.07	0.31

Table 1c: Animal protein feed resources for smallholder poultry production

Feed Ingredients	Dry matter (%)	Crude protein (%)	Ether extract (%)	Crude fibre (%)	Calcium (%)	Phosphorus (%)	Lysine (%)	Methionine (%)
Blood meal	89.0	80.0	1.0	1.0	0.28	0.22	6.90	1.00
Earthworm (dried)	91.4	63.0	5.9	1.9	0.53	0.94	6.35	5.30
Feather (dried)	93.0	85.0	4.0	1.5	0.20	0.70	2.05	0.65
Garden snail (dried with shell)	91.0	66.8	7.9	4.1	1.13	0.15	5.10	1.33
Housefly maggot (dried)	88.5	60.0	19.0	0.5	0.20	0.20	3.60	1.40
Local fish meal	92.0	39.0	8.5	0.4	3.00	1.80	3.00	0.90
Termite meal	96.3	46.3	30.1	7.3	0.23	0.38	2.83	1.68
Unskinned dried tadpole	93.2	43.5	11.3	3.8	0.25	0.57	6.97	2.08
Unskinned boiled tadpole meal	93.4	45.9	10.7	3.8	2.43	0.42	6.72	1.74

Table 1d: High-fibre feed resources for smallholder poultry production

Feed Ingredients	Dry matter (%)	Crude protein (%)	Ether extract (%)	Crude fibre (%)	ME (kcal kg^{-1}) (%)
Brewer's wet grain	22.30	27.80	8.00	12.60	3320
Brewer's dry grain	84.30	17.00	6.80	13.20	
Corn cobs (dried, milled)	89.00	2.30	0.40	35.00	523
Cottonseed hulls	90.00	4.00	4.40	43.00	-
Okra, (dried fruit)	87.50	14.63	9.75	36.90	1622
Okra, (seeds from dried fruit)	86.22	19.66	13.34	34.60	1700
Palm kernel meal	90.00	21.30	4.40	17.50	2500
Poultry manure, dried, cage	89.00	28.70	1.70	14.90	-
Poultry manure, dried, floor	85.00	25.30	2.30	18.60	-
Rice hulls	92.00	3.00	0.50	44.00	720
Rice bran	91.00	13.50	5.90	13.00[7]	2040
Rice grain with hulls	93.93	11.17	1.89	9.02	2986
Rice grain, hull removed (brown rice)	94.38	12.51	0.21	0.19	3463
Rice offal (unparboiled)	90.00	5.50	3.50	30.00	1300
Rice offal (parboiled)	90.00	3.50	3.00	36.00	1200
Sorghum offal	91.00	9.00	5.00	6.00	2700
Tomato pulp, dried	93.00	21.00	10.00	25.00	1760
Wheat bran	89.00	14.80	4.00	10.00	2320
Wheat offal	89.00	15.00	3.50	8.50	1870

Table 1e: Mineral feed resources for smallholder poultry production

Feed ingredients	Calcium (%)	Phosphorus (%)
Bone meal	32.00	12.50
Dicalcium phosphate	22.00	-
Limestone	35.00	-
Oyster shell	35.00	-
Periwinkle shell	32.00	-
Eggshell meal	35.20	0.12

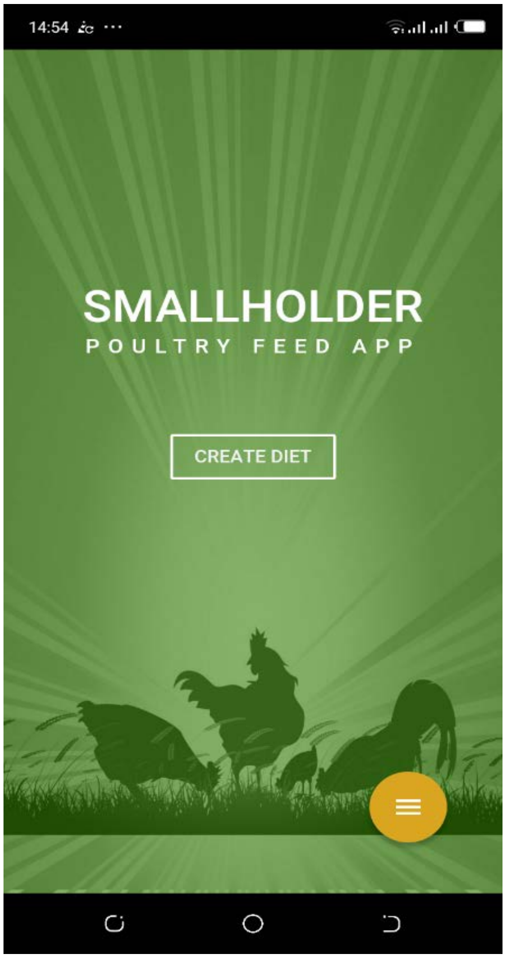

Fig. 3: The landing screen of the app

Android, iOS and Windows versions are available at their respective app stores. The app can be used to formulate supplementary feed for grower and layer birds (Fig. 4) and presents the calculated nutritional content (ME, CP, phosphorus and calcium) of the formulations. The app also alerts the user if there are calcium or phosphorus deficiencies in layer diets (Fig. 5). The app result screen shows the quantities of each of the ingredients to be mixed to make the formulation (Fig. 6) and includes the quantities specified by the user at the beginning of the process. From the result screen, the user can view pie charts of the diet by ingredient proportions in the mixture (Fig. 7) and by each ingredient's protein contribution to the formulation (Fig. 8); the user can also review and edit the ingredients used in the formulations and export the app-produced formulations to Excel.

The LAFR found in the crops of scavenging chickens in the two field test locations are presented in Table 2. Table 3 shows that grower chickens on ScAS had an average daily gain that

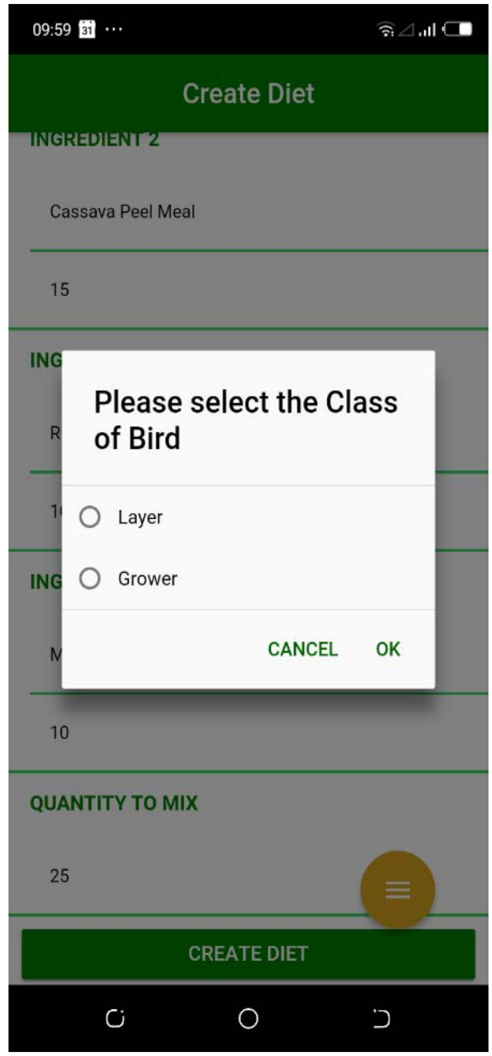

Fig. 4: Confirmation of bird class screen prior to feed formulation

was 49, 121 and 510% ($p<005$) that of the CPD, ScFS and ScNS chickens, respectively. There was no significant difference in the final body weight or average daily gain of growers between the ScAS and ScFS treatments; however, the ScAS birds had higher average daily feed intake and lower feed conversion ratios than the ScFS birds.

DISCUSSION

The simplicity of the interface, availability of options for specifying available ingredients and their quantities and ability to specify the desired output quantity make the app helpful to SP farmers[7]. Displaying the formulation in pie chart form is in agreement with the recommendation of Afolayan

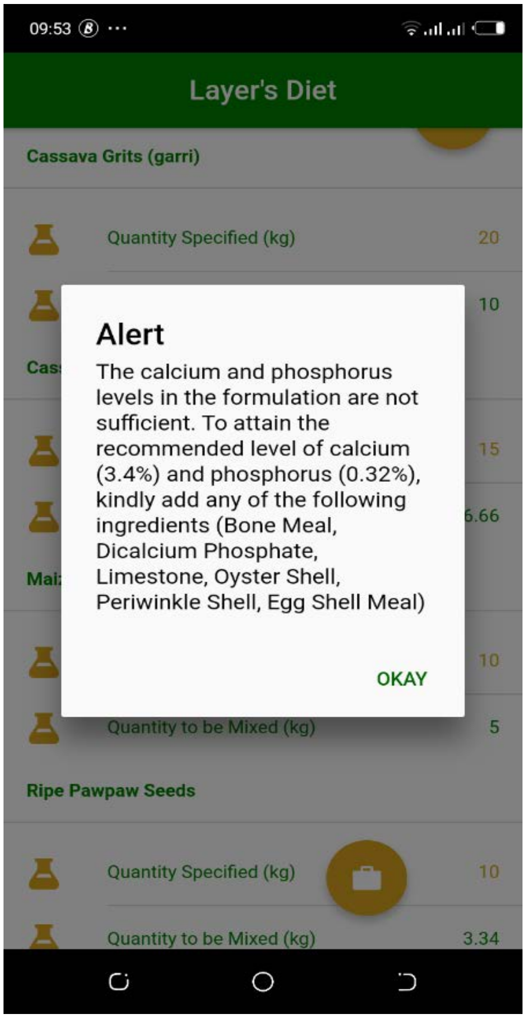

Fig. 5: Alert showing insufficient calcium and phosphorus in the formulation, with suggested ingredients to include to ameliorate this concern

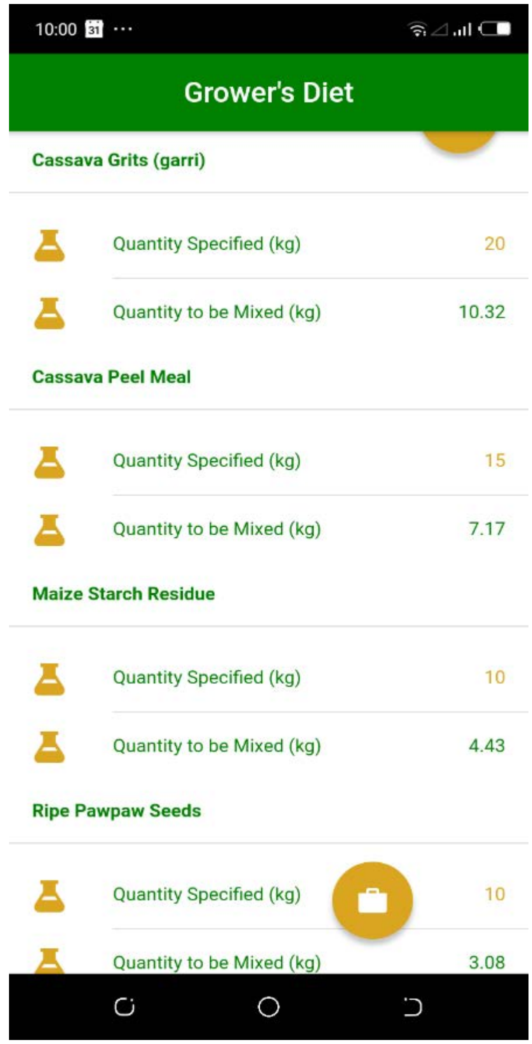

Fig. 6: Result screen showing the quantities specified and quantities to be mixed for each selected ingredient

Table 2:The feed resources isolated from the crops of scavenging chickens in the study locations

	Location	
Nutrient source	Ifetedo	Oloki-ede
Energy	Maize, sorghum, maize starch residue, bread waste, gaari sieving, eba, amala, cassava peel, yam flour sieves*	Maize, broken rice grains (local), bread waste, sorghum, eba, amala, pounded yam, soybean testa*, cowpea testa*, maize starch residue
Fibre	Pawpaw seeds, orange pulp*, orange seeds*, pawpaw seeds	Rice bran*, palm fruit pulp*, pawpaw seeds, palm kernel cake
Plant protein	Locust beans*, groundnut	Boiled beans*, roasted groundnuts
Animal protein	Earthworms, soldier ants, cockroach, dried fish*	Earth worms, housefly*, cockroach, soldier ants, maggot*

*-indicates feed resources present in only one location

Table 3: Six- to sixteen-week performance of grower birds in villages during the application-formulated supplementary feed field test

Treatments	Confined with proprietary diet	Scavenging with app-formulated supplement	Scavenging with farmer's supplementation	Scavenging with no supplementation
Initial body weight (g)	421.00^{a}	374.000^{d}	392.00^{c}	399.0^{b}
Final body weight (g)	$2,535.00^{a}$	1.455^{bc}	1.191^{b}	536.0^{c}
Average daily gain (g)	29.70^{a}	14.600^{ab}	12.10^{ab}	2.9^{c}
Average daily feed intake (g)	106.00^{a}	88.000^{b}	84.00^{c}	-
Feed conversion ratio	4.06^{c}	7.040^{b}	8.46^{a}	-

$^{a-d}$Means with different superscripts on the same row were significantly different at $p<0.05$

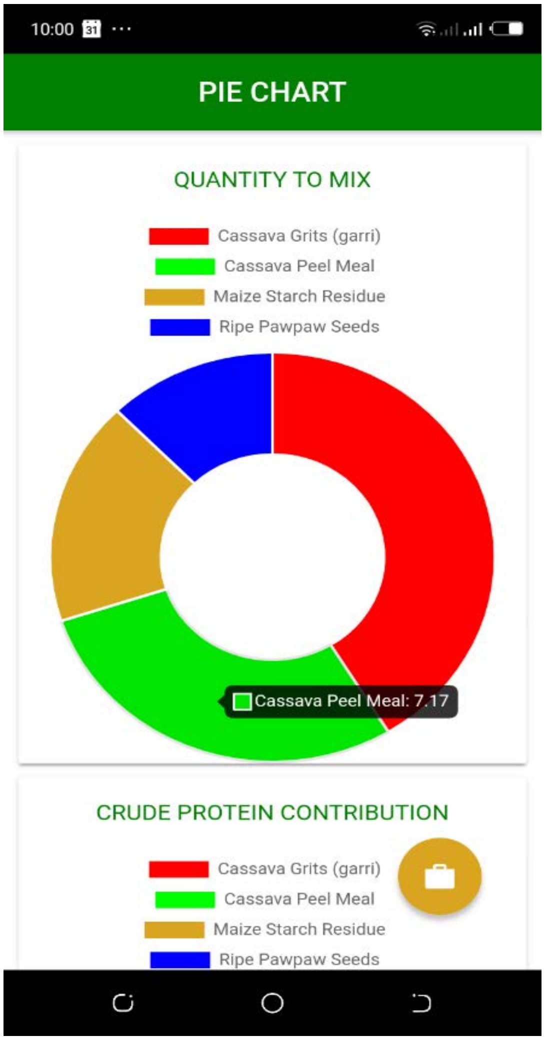

Fig. 7: Pie chart showing the proportions of the ingredients in the formulation

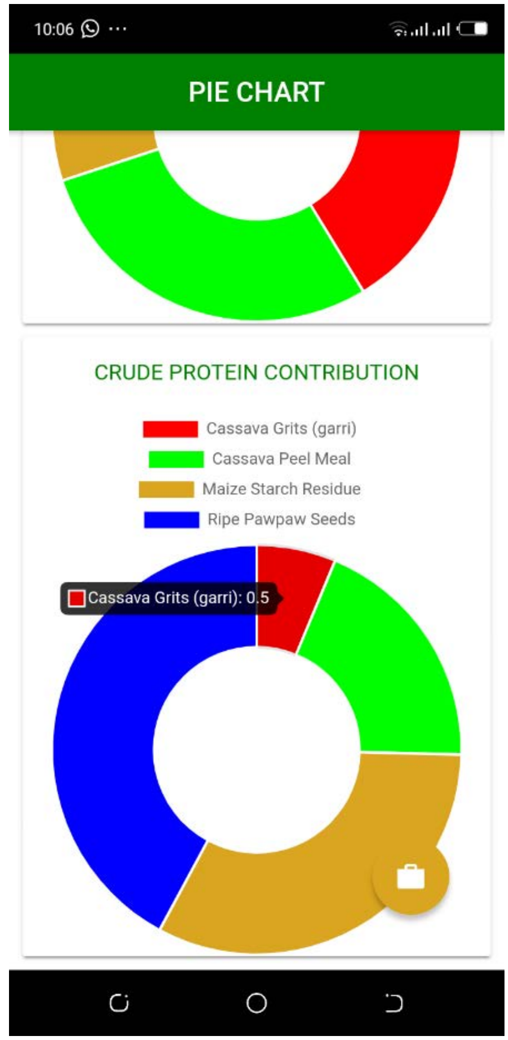

Fig. 8: Pie chart showing the crude protein contributions of each of the ingredients

and Afolayan[7] who suggested that supplementary feed formulation software for SP farmers should provide a visual interpretation of the formulation results. Free-ranging birds have been reported to obtain 10.5-14.2% of their CP intake from scavenging[10,11]; a supplementary feed that contains 8% CP will meet the total CP requirement (16 and 17%), required for growers and layers, respectively.

The field test indicated that the Smallholder Poultry Feed App helped rural poultry farmers to optimise the LAFR around them. The nutritional quality of the app-formulated diets could be further improved by increasing the number of ingredients that can be included in the app formulation. The lack of a significant difference in the final body weight and average daily gain of the experimental birds between the ScAS and ScFS treatments could be a result of the limited number of ingredients that can be used by the app in making formulations (maximum of four). This restriction in the number of ingredients might prevent or restrict proper nutrient balance in the diet.

CONCLUSION

Scavenging grower birds fed an app-formulated supplementary diet had significantly improved performance compared to birds that were fed farmer-provided supplementary diets or not fed any supplements at all. The Smallholder Poultry Feed App enabled the utilisation of LAFR in the field test villages. The quantity and quality of the nutrients supplied by scavenging are insufficient to meet the nutritional requirements of scavenging grower chickens;

supplementation is required, preferably from LAFR. This app helped SP farmers meet this supplementation requirement by identifying LAFR and using LAFR in the formulation of simple supplementary diets for scavenging grower and layer chickens.

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