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ORIGINAL RESEARCH ARTICLE

Availability of Pickable Residual Feed Base for indigenous chickens (*Gallus gallus domesticus*) in a rural village in Madagascar

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ABSTRACT

Village poultry production in Madagascar relies on free-range rearing of indigenous chickens (Gallus gallus domesticus), which feed mainly on the Pickable Residual Feed Base (PRFB) consisting of household waste and natural resources. This low-input feeding system is particularly limiting during the dry season. This study assessed PRFB availability by combining household waste quantification, crop content analysis, and chicken performance monitoring in a rural village of the Analamanga region. PRFB was estimated using two waste-based methods (443.2 g per family flock and 47.2 g per chicken per day on average) and one productivity-based method indicating a theoretical annual metabolizable energy requirement of 282.3 kg per family flock.

As a result, the average daily gain varies from 4.1 g/day during harvest to 2.8 g/day during dry periods, and the protein content of crop residues varies from 11.5% DM to 6.2% DM. Finally, the study also identified pigeon grass seeds (Eleusine indica), locally known as “Tsipipihana”, as an important unconventional feed resource exploited by scavenging chickens.

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1. INTRODUCTION

In Madagascar, village poultry plays a crucial role in rural livelihoods by providing an important source of animal protein, nutrition security, and supplementary income for smallholder families. The productivity and size of these flocks depend heavily on the availability of the Pickable Residual Feed Base (PRFB), which constitutes the main nutritional resource for indigenous scavenging chickens. A positive correlation is observed between egg production and the amount of food ingested. This relationship is illustrated by the case of Bangladesh, where egg production declines during the heavy rains of August and September and increases significantly in January and February, when snails, an important food source for chickens, are abundant (Horst, 1986, as cited in FAO, 2004). Similar seasonal patterns have been reported in sub-Saharan Africa, with lower productivity during the dry season due to reduced availability and quality of scavengeable feed resources (Goromela et al., 2008; Raphulu et al., 2015; Alders, 2018).

According to estimates by the French Environment and Energy Management Agency (ADEME), each individual generated an average of 300 kg of household waste per year in 2015, based on the quantities collected by local authorities, excluding green waste. A significant proportion of this waste can be recycled into animal feed. For example, a hen can consume up to approximately 75 kg of organic matter, including food scraps, peelings, dry bread, etc., according to Dumat (2018).

Although these figures originate from urban contexts in high-income countries, they illustrate the general potential of household organic waste as a recyclable resource for animal feeding. In rural Madagascar and other low-input systems in sub-Saharan Africa, kitchen scraps, crop residues, and agricultural by-products similarly constitute the main components of the Pickable Residual Feed Base (PRFB) for indigenous chickens, contributing to waste valorization and reduced feed costs for smallholder farmers (Sonaiya, 1995; Alders, 2018; Raphulu et al., 2015). Research conducted in Nigeria, according to Sonaiya (1995), has made it possible to compile an inventory of food resources available to small farmers. These resources consist mainly of kitchen scraps and agro-industrial by-products, which are also found in many tropical countries, confirming the importance of local recycling of organic waste to support animal production.

Indigenous chickens adopt a foraging feeding pattern, deriving most of their nutrition from natural resources available in their environment, such as seeds, insects, vegetation, and various organic debris (Ndriamboavonjy, 1979). These naturally available resources, when supplemented by crop residues, forms what is known as the Pickable Residual Feed Base (PRFB). According to Sonaiya et al. (2004), the PRFB corresponds to the total amount of food available to stray animals in a defined geographical area. It consists mainly of domestic waste, but also includes a variety of natural elements such as insects, worms (especially earthworms), succulent vegetation, flowers, fruits, agricultural by-products, and processing residues, according to Sonaiya et al. (2002a).

Specifically, the study sought to characterize household food waste and crop contents while determining their nutritional composition. Furthermore, it aimed to quantify seasonal variations and estimate the PRFB using different methods to assess its relationship with the average daily gain of chickens. Previous research has shown that the amount of food resources consumed by free-range chickens depends on a number of factors, including climatic variations, the availability of grain at the household level, and sowing and harvesting periods (Cummings, 1992; Roberts, 1995; Tadelle, 1996; Sonaiya et al., 2004). In addition to these elements, there are structural factors that can influence the availability of food resources, including the number of households, the diversity and density of family farms, and the nature of the crops grown. The total biomass exploited by free-range chickens is directly proportional to the amount of PRFB, according to Sonaiya et al. (2004).

Regarding methods for estimating PRFB, Roberts (1992) proposed two approaches for estimating the amount of recoverable feed, including the analysis of crop contents, which allows for the assessment of the proportion of household waste consumed. Additionally, an indirect estimation based on hen productivity was suggested, considering the relationship between feed consumption and laying performance. These methods involve direct handling of the chickens, which may limit their application on a large scale. However, according to Sonaiya (2011), even if these techniques do not provide perfectly accurate measurements, they are relevant indicative tools. The author points out that greater accuracy could be achieved by simultaneously integrating chicken's production data and seasonal variations affecting food availability.

2. MATERIALS AND METHODS

2.1 Study setting

2.1.1 Area selected for the study

The study was conducted in Madagascar, in the Analamanga Region, within the rural commune of Talatavolonondry, specifically in the Mamoriarivo Fokontany (the smallest administrative unit in Madagascar). Although the study site was selected based on accessibility and the willingness of local farmers and livestock keepers to cooperate, this convenience sampling may limit the generalizability of the findings to other rural areas in Madagascar.

2.1.2 Study periods

In order to collect representative data and increase the chances of identifying the consumption of unconventional foods, this study was conducted over three distinct periods spread over a year, corresponding to the main local agro-climatic seasons:

- Harvest period (main rice harvest): April to May

- Dry season (southern winter): May to October (T° 25°C) (Club Med, 2024). Data collection for this season was specifically carried out during the month of July to represent the peak of the dry and cold period.
- Rainy season: November to March (T° 27°C to 30°C) (Club Med, 2024)

2.1.3 Sampling methods and sample size

2.1.3.1 At the level of local competent authorities

An official approach was made to the rural commune office and the fokontany office to inform and raise awareness among the administrative authorities about the objectives of the study and the implementation protocol. These authorities were asked to provide two types of information essential to the smooth running of the research, starting with the surface area of the village to enable an accurate assessment of the area covered by free-range chickens. Additionally, data regarding the types of crops grown during the current year were requested in order to better understand the potential sources of food residues available in the village environment.

2.1.3.2 At the household level

Based on a survey conducted in southwestern Nigeria, Olukosi and Sonaiya (2003) selected thirty-four free-range chicken's farmers, each with at least ten chickens, minimal shelter, and a supplementary food supply. In this study, a sample of thirty-six households was selected at random, including both chicken-keeping farmers and non-chicken-keeping farmers. These households were monitored longitudinally through repeated visits each season, allowing for a comparative analysis of the data collected between the different observation periods, while taking into account the chickens status of each household.

2.2 Data collection on household and agricultural practices

Data were collected using standardized questionnaires and direct observations in the field. Semi-structured interviews were conducted with members of the selected households, scheduled according to their availability as identified during the initial census. This approach was designed to ensure a consistent, contextualized, and representative data collection. The semi-structured questionnaire included items on chicken farming practices, types and quantities of food resources used for chickens, household socioeconomic characteristics, income sources, and livestock ownership. A detailed version of the questionnaire is provided as supplementary material. The questionnaire covered chickens farming practices, the food resources used, and the general socioeconomic characteristics of households. Informed consent was obtained from all participating households prior to their inclusion in the study. Due to the low literacy rates in the rural study area, verbal informed consent was obtained after providing a full explanation of the study in Malagasy. All procedures involving human participants (household surveys and interviews) and animals (crop content analysis) were conducted in accordance with ethical standards for research. The study objectives, procedures, voluntary nature of participation, right to withdraw at any time, and confidentiality measures were clearly explained before each interaction. Verbal agreement was confirmed and recorded for each household.

2.2.1 Variables collected for socioeconomic stratification

During the initial visit, a cross-sectional study was conducted using questionnaires and field observations to describe the socioeconomic status of the surveyed households. The information collected for this stratification included general household characteristics such as size, composition, and level of education, alongside the identification of main income sources and estimated monthly income. Additionally, data were gathered regarding the types and quantities of agricultural products from crops, as well as the type and number of livestock owned, with a specific focus on the total number of chickens in the household. These basic data allow households to be stratified according to their economic profile, and provide a better understanding of their capacity to supply food resources for indigenous chickens.

2.2.2 Professional activities and monthly income

Sources of income and monthly household income are factors that can significantly influence PRFB. Households with higher incomes often produce more food residues, which are both more abundant and of higher quality. Thus, economic disparities between households directly translate into differences in the quantity and quality of food resources available to free-ranging animals, particularly indigenous chickens.

2.2.3 Material possessions

Household material possessions are also a key indicator that influences PRFB. According to Gunaratne et al. (1994a, 1994b & 1994c), there is a direct correlation between the total biomass of free-ranging chickens and the amount of PRFB available. Thus, when there is a surplus of PRFB, for example following a good harvest or a reduction in the number of livestock, chicken's performance improves, resulting in better survival and increased egg production. Conversely, a deficit of PRFB results in lower productivity, increased mortality, and reduced egg production.

2.3 Bromatological analyses of the crop contents of free-range chickens

Bromatological analyses were performed in a specialized animal nutrition laboratory. Macronutrients (dry matter, crude protein, crude fat, starch, and ash) were determined by near-infrared spectroscopy (NIRS). Predictions were based on pre-existing calibration models developed for poultry feed and scavenging chicken crop content matrices. These models demonstrated high predictive robustness, with cross-validation coefficients of determination (R^2cv) ranging from

0.85 to 0.96, standard errors of calibration (SEC) from 0.83 to 3.86, and standard errors of cross-validation (SECV) between 0.85 and 3.89.

During this study, spectra were acquired from local samples and processed using these established equations without further re-calibration, and to ensure high precision, each sample was scanned 5 to 10 times at different positions, and the average value was retained after removing any outliers. Otherwise, calcium, phosphorus, and insoluble ash were analyzed using standard wet chemistry methods (AOAC, 2019). Finally, a qualitative visual examination of the crop contents was carried out to identify specific feed items and potential contaminants.

2.4 PRFB estimates

2.4.1 Method based on household waste weight

This method involves quantifying the weight of household waste and estimating its proportion in the contents of chickens' crops. Daily waste collection over 14 consecutive days was carried out in the same 36 selected households during each of the three seasons (harvest, dry, and rainy), resulting in longitudinal repeated measures per household, in accordance with the methodology described by Gunaratne et al. (1993). The same households were revisited across seasons to allow direct seasonal comparison while accounting for household-specific effects in statistical analyses. Each household was given a colander and a plastic bag to collect food waste continuously over a 24-hour period. Only edible food waste and organic residues suitable for chicken consumption were collected and weighed, and non-food materials (such as plastic and paper) were systematically excluded. The components of the waste were then identified by visual inspection and weighed individually, according to the procedure described by Olukosi and Sonaiya (2003), as illustrated in **Figure 1**.

At the end of each collection season, a sample of chickens was slaughtered in order to collect and analyze the contents of their crops, with the aim of establishing a link between the composition of household waste and the actual feed intake. All procedures involving animals were conducted in accordance with institutional guidelines for animal welfare and ethical standards for animal experimentation.

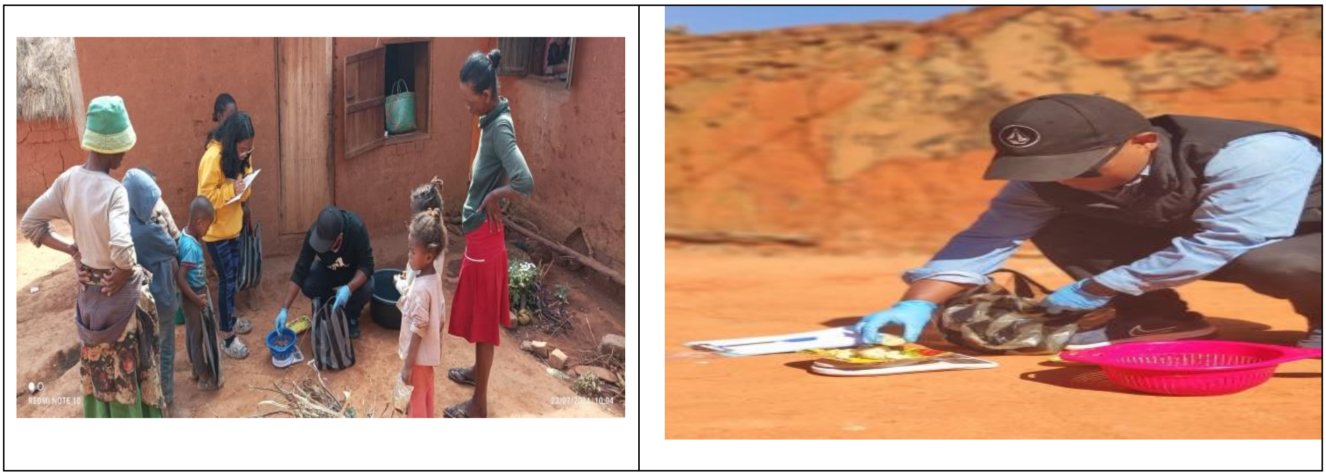

Fig. 1. Collection and weighing of household waste

2.4.1.1 Calculation basis according to Roberts' equation (1992)

The approach proposed by Roberts (1992) allows the total amount of food resources available within a rural community to be estimated, based on daily household waste production and taking into account the number and type of livestock, particularly free-range indigenous chickens. The amount of available food resources was estimated using the equation developed by Roberts (1992):

PRFB = [H/P] *[n/(n-x)]

Where:

PRFB = Pickable Residual Feed Base (g/family flock),
H = Household waste (g/day),
P = Proportion of H in crop content,
n = Total households in the village, x = Households without chickens.

2.4.1.2 Calculation basis according to the formula by Sonaiya et al. (2002b)

The objective of the method amended by Sonaiya et al. (2002 b) remains similar to that of the method initially developed by Roberts (1992). However, it introduces a more refined approach by emphasizing the assessment of feed that can actually be recovered by chickens in a low-input village farming context. This method aims to provide a more

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realistic and contextualized estimate of the nutritional resources available locally for feeding indigenous chickens:

RF = [H/P]*[n/T]

Where:

RF = recoverable feed (g/chicken/day),

H, P, and n = as defined above, T = Total chickens in the village.

2.4.1.3 Method based on the productivity of scavenger chickens

This approach aimed to estimate the theoretical metabolizable energy requirement needed to support the observed growth and production levels of chickens in family flocks. It differs from the two previous waste-based methods, which estimate the actual PRFB availability in the environment. The productivity-based method therefore indicates the minimum feed quantity theoretically required, rather than the amount of feed actually available (Roberts, 1992). During each season, male and female specimens of local breeds were monitored longitudinally over an eight-week period. These free-range chickens were weighed weekly to assess their growth, as illustrated in **Figure 2**.

Fig.2. Three-day-old local chicks weighed on electronic scales as part of weekly weight monitoring

At the end of the observation period, the specimens were captured while feeding and immediately slaughtered to prevent emptying of the crop. The crop was then opened to allow visual identification of the ingested items and recording of the weight of its contents. At the same time, all eggs laid during the eight-week observation period were weighed individually for every hen in the monitored flocks to calculate egg mass, rather than estimated from a subset. The amount of recoverable feed (kg/family flock/year) was then calculated from the zootechnical performance observed, using the formula proposed by Roberts (1992):

PRFB = [∑Ej] / Es

Where:

PRFB = Pickable Residual Feed Base (kg/family flock/year),

j = average flock size,
Ej = metabolizable energy requirements for maintenance and daily production of each bird (kcal/bird),
Es = metabolizable energy in the pecked feed (kcal/kg dry matter).

Ej was calculated to determine the metabolizable energy requirements for maintenance and daily production of free-range chickens over an eight-week period using the NRC (1994) formula:

$$\mathbf{E_j = W^{0,75}\ (173-1.95T) + 5.5\ \Delta W + 2.07EE}$$

Where:

Ej = metabolizable energy requirements for maintenance and daily production of each bird (kcal/bird),

W = average body weight (kg), T = ambient temperature (°C),

ΔW = body weight gain (g/bird/day), EE = daily egg mass (g).

In this formula:

- W0.75 (173-1.95T) represents the energy requirements for body maintenance.

- 5.5 × ΔW represents the energy requirements for growth.

- 2.07 × EE represents the energy requirements for egg production.

Figure 3 shows the chickens that were individually monitored for weight. Variations in weight were recorded throughout the different phases of the study.

Fig. 3. Illustration of chickens wandering around looking for food in the yard and around homes

2.5 Data collection, processing and analysis

Socioeconomic variables were aggregated into a composite index to classify households into three levels (Razafindratsima, 2022). Data were analyzed using R Studio (version 2023.12.1). Two-factor ANOVA was used to test the effects of season and socioeconomic status on the quantity of household food waste, followed by Tukey's post-hoc tests for pairwise comparisons. Multiple linear regression was performed to assess the combined influence of socioeconomic status and household size on waste production. The assumption of normality was verified using the Shapiro-Wilk test. Repeated measures by household across seasons were taken into account in the statistical models.

3. RESULTS AND DISCUSSION

3.1 Socioeconomic and zootechnical characteristics of village poultry production

According to interviews with local officials, the village of Mamoriarivo covers an area of 5 km2, where rice is the dominant crop. During the dry season, these rice fields are typically repurposed for "voly avotra," which involves the off-season cultivation of peas and beans. Other food crops, including cereals, legumes, and tubers such as corn, cassava, cowpeas, sweet potatoes, and beans, are generally sown between October and March, which corresponds to the region's rainy season.

3.1.1 Demographic structure of households

The demographic structure of households showed that children represent 36.8% of the members, while adults (men and women) constitute 63.2%. Analysis of the averages per household reveals a slight numerical predominance of children over adults. A wide dispersion of data shows that household composition is very diverse, particularly with regard to the number of children.

3.1.2 Distribution of household activities and income profile

Agriculture is the main economic activity of households in the village, followed by livestock farming combined with other sources of income. A significant proportion of households engage in several activities simultaneously. Among secondary activities, trade accounts for 36% of households, crafts (carpentry, mechanics) 30%, and day labor 19%. Finally, 5% are engaged in administrative functions, particularly in education or office services. In terms of monthly income, more than half of households earn less than 200,000 Ariary, around 22% have an income of between 200,000 and 400,000 Ariary, while 19% earn more than 400,000 Ariary. This distribution highlights the existence of significant economic disparities within the community, which may influence the access to resources and the ability to provide food for farm animals.

3.1.3. Diversity and distribution of livestock in households

Households in the village own a variety of livestock, mainly chicks, followed by chickens and pigs. Other animals, such as zebu cattle, rabbits, and broiler chickens, represent a relatively small proportion of the total livestock population. The high standard deviations observed in relation to the averages revealed a significant dispersion, indicating that some households own many more animals than others, which points to clear differences in the resources available for livestock farming within the community.

3.1.4. Evaluation of scores and classification of socioeconomic levels

The evaluation of the value of agricultural products and socioeconomic scores made it possible to classify households into three main categories. Specifically, level 1, representing a very low socioeconomic status, included 80.6% of households, while level 2 (low) and level 3 (average) accounted for 13.9% and 5.6% of the households, respectively. The scores revealed a wide variation in the number and value of farmyard animals as well as in the total value of livestock. High values were rare, while the majority of households fall within a medium range, reflecting an uneven distribution of resources within the community.

3.2 Analysis of food waste and its contextual determinants

3.2.1. Availability and diversity of food waste according to socioeconomic status and season

During visits to households, the importance of collecting food waste for free-range chickens was highlighted, with a particular focus on waste that was actually included in chickens' feed. This waste was then identified and weighed. The results are shown in **Figure 4**.

Analysis of household food waste revealed that both season and socioeconomic status significantly influenced the quantity and diversity of residues available to indigenous chickens (Figure 4). Daily waste production was highest during the harvest period, reaching an average of 317.5 g per household, compared to 274.8 g in the dry season and 198.8 g in the rainy season (see also Table 6). Households in higher socioeconomic levels (levels 2 and 3) consistently generated larger volumes of waste and more diverse residues than level 1 households across all seasons. In terms of quality, the compositional diversity of food waste was markedly higher during the harvest season, with greater contributions from rice residues, kitchen scraps, and fruit peelings. This seasonal peak in both quantity and variety explains the higher crude protein content observed in crop contents during the harvest period (11.5% DM) compared to the dry season (6.2% DM).

3.2 2 Observation of free-range chickens

3.2.2.1. Changes in chicken weight

During each assessment period, chickens of various ages were observed. Specifically, the study monitored 48 individuals aged 3 days to 6 months during the harvest period, 51 individuals aged 7 days to 4 months during the dry season, and 39 individuals aged 3 days to 3 months during the rainy season.

Although animal losses were recorded during these periods, they did not compromise the reliability of the data collected. Weighings were performed on a weekly basis, and the average daily weight gains for each observation season are presented in **Table 1.**

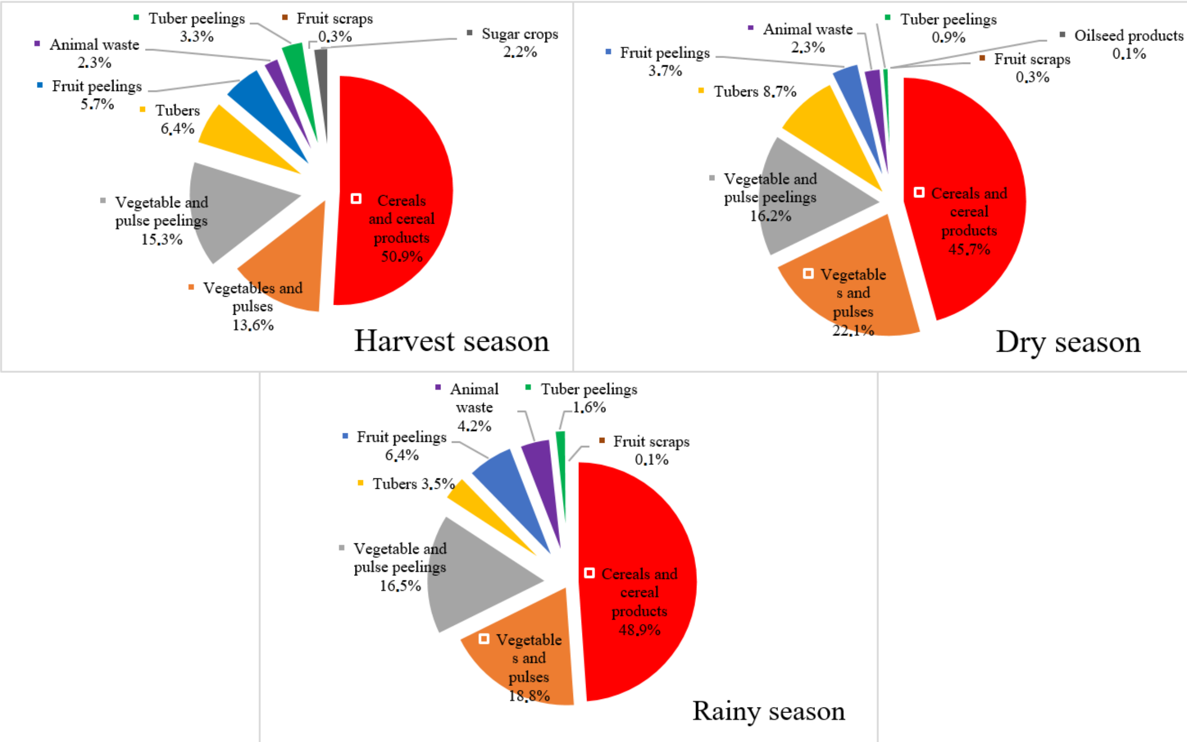

Fig.4. Composition and volume of household food waste (%) according to season

Table 1 : Daily weight gains (DWG) of free-range chickens

	Harvest period	**Dry season**	**Rainy season**
DWG (gram)	4.1	2.8	3.8

Chicken weight gains tended to decrease during the dry season, probably due to insufficient nutrient intake in extensive and small-scale systems. Similar seasonal variations in growth performance have been reported in village poultry systems in Tanzania and Ethiopia, where feed availability strongly depends on seasonal agricultural activities and natural feed resources. These observations confirm the role of PRFB as a major factor influencing the growth of free-range chickens, in line with the findings of Sonaiya et al. (2004). However, it should be noted that the age ranges of monitored chickens differed across seasons (up to 6 months during the harvest period, 4 months in the dry season, and 3 months in the rainy season). Because growth rate is age-dependent, direct comparisons of average daily gain must be interpreted with caution. This represents a limitation of the study. **Figure 5** illustrates the progression of chicken growth, showing cumulative weight gain from zero in order to visualize weight accumulation since the start of the study.

3.2.2.2. Observation of crop contents of free-range chickens

After the chickens were slaughtered, the contents of their crops were extracted, identified, and weighed accurately. Figure 6 illustrates the diversity of food resources ingested by the chickens, which included cereals such as paddy rice, cooked rice, and rice grains, as well as animal proteins including crickets, caterpillars, ants, earthworms, and other insects. Furthermore, the crop contents contained plants like green plants, cooked leaves, and lychee bark, along with domestic waste such as potato peelings.

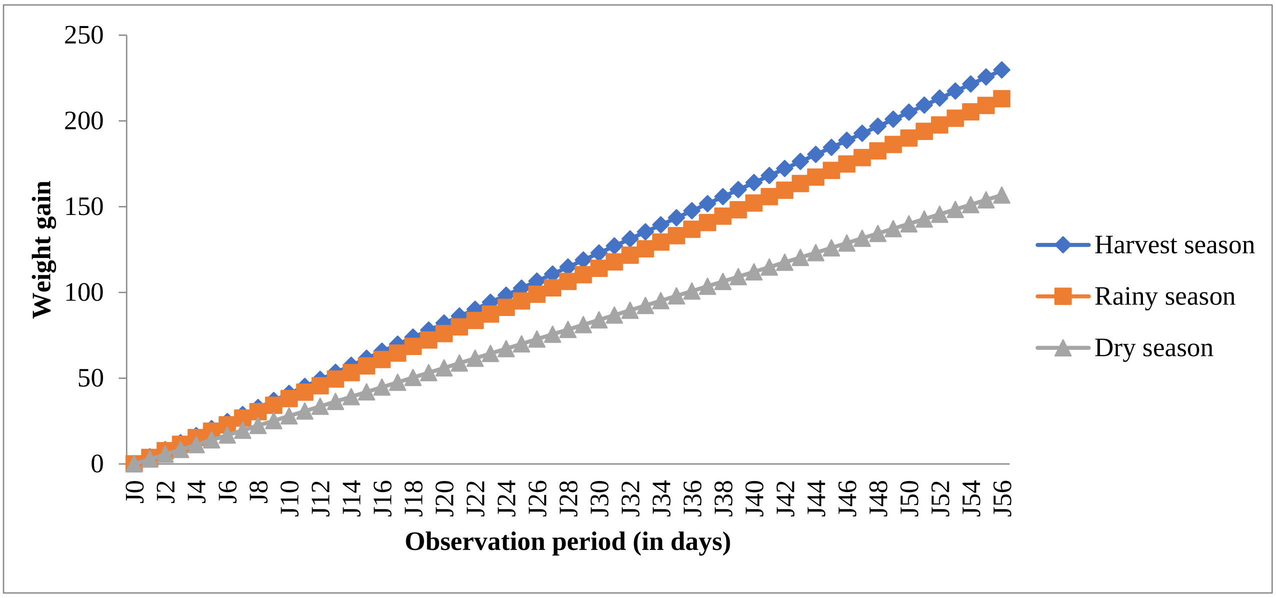

Fig. 5. Comparison of daily weight gains in chickens according to season

Fig.6. Illustration of the contents of chicken crops

This dietary diversity highlights the ability of indigenous chickens to exploit a wide range of resources available in their environment, which contributes to their resilience and performance in extensive systems.

3.2.2.3. Nutritional profile of crop contents of free-range chickens

The results of the analysis of the crop contents of the chickens, presented in **Table 2,** provided essential data for assessing the nutritional quality of the chicken's current diet. This study made it possible to determine whether essential nutrients, such as protein, carbohydrates, lipids, minerals, and fiber, are provided in sufficient and balanced quantities, thus ensuring that the feed is adapted to the physiological needs of the chickens and promotes their health, growth, and productivity.

In addition, this nutritional assessment helped prevent deficiencies and excesses, while limiting food waste. A higher crude protein (CP) content was noted during the harvest season. With regard to Fat Matter (FM), the value recorded in Mamoriarivo during the harvest period (78 g/kg DM) exceeded the established African averages (approximately 26.6 g/kg DM), This high fat content may be linked to culinary or oilseed residues, although direct attribution requires further confirmation

Table 2. Seasonal profile of the nutritional composition of crop contents (%DM)

Nutrients	Dry season (n=20)	Rainy season (n=20)	Harvest season (n=20)
DM	50.2	58.7	53.1
MM	6.6	10.2	9.9
Ca	0.29	0.68	0.56
P	0.61	0.82	0.54
CP	6.2	8.9	11.5
FM	2.8	2.9	7.8
St	62.9	58.3	65.0
Es (kcal/kg DM)	3834	3693	3616

DM: Dry Matter; MM: Mineral Matter; Ca: Calcium; P: Phosphorus; CP: Crude Protein; FM: Fat Matter; St: Starch; Es: Metabolizable Energy in pecked feed; n: number of slaughtered chickens

3.3. Results of PRFB estimates

Three different approaches were used to estimate the Pickable Residual Feed Base (PRFB). The first two methods are based on household waste quantification and crop content analysis; they provide an estimate of the actual PRFB availability in the village environment. While the first method estimates the total resources available per family flock, the second offers a more granular practical interpretation by calculating the feed recoverable per individual bird. In contrast, the third method is based on the observed zootechnical performance of the chickens and calculates the theoretical metabolizable energy requirement needed to support maintenance, growth and egg production. It is therefore important to distinguish between these approaches: the 282.3 kg per family flock per year represents the minimum theoretical feed requirement, and not the actual amount of feed available in the environment (Roberts, 1992).

3.3.1. Method based on household waste and number of flocks in the village

This method consisted of quantifying the mass of household waste and its relative proportion in samples taken from the crop contents of chickens. In accordance with the formula developed by Roberts in 1992, the average estimates of potentially recoverable food resources per season are presented in **Table 3.** The results revealed a seasonal variation in the food resources available to chickens, with a peak during the harvest period (PRFB: 597.6 g per flock) and a trough during the rainy season (PRFB: 302.6 g/flock), thus reflecting the rhythm of local agricultural activities.

Table 3. Pickable Residual Feed Base (g/family flock)

Seasons	H	P	n	x	PRFB
Rainy season	198.8	0.96	102	32	302.6±170
Harvest season	317.5	0.78	102	32	597.6±356
Dry season	274.8	0.93	102	32	429.5±277
AVERAGE	263.7±60	0.89±0.1	102	32	443.2±315

PRFB=Pickable Residual Feed Base (g/family flock); H= Household waste (g/day); P=Proportion of H in crop content; n= Total households in the village; x= Households without chickens

3.3.2. Method based on household waste recoverable by chickens

The equation developed by Sonaiya et al. (2002b) is based on both the quantity of household waste and the total number of households and chickens in the village. It allows for an accurate estimate of the food potentially recoverable per chicken. The average values obtained are presented in **Table 4.** The estimate of pickable residual feed base in Mamoriarivo showed a significant contribution, with an average of 47.2 g per chicken per day, according to the formula of Sonaiya et al. (2002b). However, this value masks significant seasonal variability, with the available quantity ranging from 63.6 g/chicken/day during the harvest period to 32.3 g/chicken/day during the rainy season. This seasonal fluctuation, similar to that observed using Roberts' method, is consistent with the observations of Mwalusanya et al. (2002), which highlighted the fact that the pickable residual feed base is closely linked to the local agricultural cycle.

3.3.3. Method based on the productivity of scavenger chickens

The basic quantities of pickable residual feed base estimated for a family flock over one year, according to the different seasons, are presented in Table 5. It details the values calculated for each season (Harvest, Dry, and Rainy) by taking into account the metabolizable energy requirements for maintenance and daily production (Ej), as well as the energy contained in the pecked food (Es). Beyond these factors, the calculation incorporates the average size of the flock (j) to determine the resulting PRFB value.

This metabolic approach estimated a stable annual intake of 282.3 kg per family flock. However, this value represents the theoretical minimum metabolizable energy requirement needed to support the observed growth and egg production, rather than the actual PRFB available in the village environment (Roberts, 1992).

Table 4. Pickable Residual Feed Base (g/chicken/day)

Seasons	H	P	n	T	PRFB
Rainy season	198.8	0.96	102	657	32.3±18
Harvest season	317.5	0.78	102	657	63.6±38
Dry season	274.8	0.93	102	657	45.7±30
AVERAGE	263.7±60	0.89±0.1	102	657	47.2±16

PRFB= Pickable Residual Feed Base (g/chicken/day); H= Household waste (g/day); P= Proportion of H in crop content; n= Total households in the village; T = Total chickens in the village.

Table 5. Pickable Residual Feed Base (kg/flock/year)

Seasons	Ej (kcal/bird)	Es (kcal/kg de DM)	j	PRFB
Rainy season	299	3693	9.4	281.1
Harvest season	312	3616	9.4	295.7
Dry season	305	3834	9.4	270.1
AVERAGE	305±7	3714±111	9.4	282.3±13

PRFB= Pickable Residual Feed Base (g/flock/year); j=average flock size; Ej = metabolizable energy requirements for maintenance and daily production of each bird (kcal/bird); Es= metabolizable energy in the pecked feed (kcal/kg/dry matter)

3.4. Statistical analysis of the factors' influence

3.4.1. Influence of household characteristics on the quality of residues

Statistical analyses revealed that the availability of food residues varied greatly, being influenced by both the season and the socioeconomic status of households (Table 6). The sample studied presented an average of 4.53 individuals per household, with a predominance of households belonging to low socioeconomic levels. The amount of edible food waste available varied greatly depending on the season, reaching its maximum during the harvest period (317.5 g on average) and its minimum during the rainy season (198.8 g on average).

3.4.2. Influence of season and socioeconomic status

The results of the two-factor analysis of variance (ANOVA), conducted to assess the influence of season and socioeconomic status on the amount of food waste, are presented in **Table 7.**

Table 6. Descriptive statistics for the sample of households and recoverable foods resources.

Characteristic	min.	1st quartile	median	Mean	3rd quartile	max.
Household size	2	3	4.5	4.53	5	10
Socio-economic level	1	1	1	1.25	1	3
Residues (crops)	43.7 g	186.5 g	295.6 g	317.5 g	403.2 g	860.9 g
Residues (dry)	62.2 g	174.9 g	216.8 g	274.8 g	323.6 g	780.7 g
Residues (rain)	33.8 g	120.3 g	164.1 g	198.8 g	264.8 g	469.4 g

Table 2 : Results of the two-factor ANOVA (season and socioeconomic status)

Source of variance	Df	Sum of squares	Mean square	F-value	p-value	Significance
Socioeconomic status	2	410319	205159	8.676	0.000339	***
Season	2	259482	129741	5.487	0.005512	**
Interaction (socioeconomic status/season)	4	41076	10269	0.434	0.783548	
Residues	98	2317277	23646	-	-	

**Highly significant at $p < 0.01$; ***Highly significant at $p < 0.001$

3.4.3. Relationship between socioeconomic status, household size, and food waste production

Table 8 presents the results of a multiple linear regression model used to assess the combined influence of socioeconomic status (SES) and household size on the amount of waste. The results showed that SES significantly influenced waste production ($p = 0.0156$ in harvest and dry seasons, $p = 0.03$ in rainy season), while household size had no statistical impact ($p > 0.47$ in all seasons). The low R^2 values (0.15–0.17) indicate that although SES is a significant predictor, a large part of the variation in waste production remains unexplained by the model. This suggests that economic purchasing power, rather than the number of people per household, is the primary driver of PRFB availability in this community. Higher-income households likely consume and discard more diverse and higher-quality food, thereby generating larger volumes and more nutrient-rich residues for indigenous chickens. This finding aligns with previous reports linking household wealth to the quantity and quality of scavenging resources in village poultry systems (Gunaratne et al., 1994; Raphulu et al., 2015), confirming that waste generation is more a function of relative affluence than household scale.

3.4.4. Seasonal effect on chicken weight gain

The results of the analysis of variance (ANOVA), supplemented by Tukey's post-hoc test, highlighted highly significant differences between the average daily gains (ADG) of chickens according to the three seasons of observation **(Table 9).** Fluctuations in ARPB have a direct influence on chicken's growth performance. AWG varies significantly depending on the season ($p<0.001$), with a peak observed during the harvest period, reaching 4.1 g/day. This pattern was supported by the nutritional analysis of crop contents, which revealed higher crude protein (CP) levels (with 11.5% DM) during this same period. Conversely, the dry season was characterized by the lowest CP content (6.2% DM) and the lowest ADG (2.8 g/day), reflecting severe food constraints during this period of the year.

Identification of unconventional foods

Examination of the contents of certain crops revealed the presence of small seeds whose initial identification proved uncertain. In order to determine their origin, behavioral observations of chickens in their natural environment were carried out. These observations showed that the chickens regularly pecked at *Eleusine indica* seeds (known locally as Tsipipihana or "pied-de-poule"). Comparison of the pecked seeds with those found in the crops confirmed their identity.

These observations showed that chickens regularly pecked at *Eleusine indica* seeds (known locally as « *Tsipipihana* » or « *pied-de-poule* »). Comparison of the pecked seeds with those found in the crops confirmed their identity. These findings indicate that this plant constitutes a natural and actively exploited component of the diet of indigenous scavenging chickens. The spontaneous consumption of its seeds reveals an important unconventional feed resource available in the local environment. The seeds of *Eleusine indica* have a moderate crude protein content, typically ranging between 9 and 12% DM (Feedipedia, 2019 ; Regmi et al., 2004). This makes *Eleusine indica* a promising low-cost supplement for dietary diversification, particularly during the dry season when PRFB availability and nutritional quality decline. Further studies are needed to evaluate its digestibility and optimal inclusion levels in village chicken diets in order to enhance the sustainability of traditional poultry systems.

Table 3: Results of the multiple linear regression model for predicting the amount of waste

Variable	Intercept	Standard error	p-value	Coefficient SES	Standard error	p-value	Coefficient HS	Standard error	p-value	R^2
Harvest season	155.35	97.36	0.12	140.31	55.02	0.02*	-2.93	16.68	0.86	0.17
Dry season	159.82	91.15	0.09	133.35	51.51	0.01*	-11.43	15.62	0.47	0.17
Rainy season	127.18	59.34	0.04*	77.86	32.98	0.03*	-5.74	10.07	0.57	0.15

SES: Socioeconomic status; HS: Household Size; *Significant at $p < 0.05$

Table 4: Results of ANOVA and Tukey's test on seasonal weight gains

Source of variance/Comparison	Df	F-value	p-value	Significance
ANOVA on seasons	2	171.2	< 0.001	***
Post-hoc comparisons (Tukey)				
Harvest – Rainy season	-	-	0.7407	-
Dry – Rainy season	-	-	< 0.001	***
Dry – Harvest season	-	-	< 0.001	***

*** Highly significant at $p < 0.001$

CONCLUSION

This study highlighted the central role of the Pickable Residual Feed Base (PRFB) in sustaining the productivity of indigenous chickens raised under village conditions in the Analamanga region of Madagascar. The results demonstrated that the availability of PRFB varies significantly according to seasonal agricultural activities and the socioeconomic status of households, which directly influences the nutritional intake and growth performance of chickens. In particular, higher feed availability during the harvest period resulted in improved daily weight gains compared with the dry season, when food resources become more limited. These findings confirm the importance of household food residues and naturally available resources in supporting traditional free-range poultry systems. The recycling of domestic waste through village poultry farming therefore represents both an ecological strategy for waste valorization and an important economic asset for rural households.

Furthermore, the identification of *Eleusine indica* seeds as a spontaneously consumed resource suggests a promising opportunity to diversify locally available feed resources. This plant could potentially contribute to improving poultry nutrition, especially during periods when PRFB availability declines. Overall, strengthening the sustainability of village poultry systems will require the development of locally adapted feeding strategies. Future research should therefore focus on assessing the nutritional value of *Eleusine indica* and on improving the management and seasonal stabilization of PRFB resources in rural communities.

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