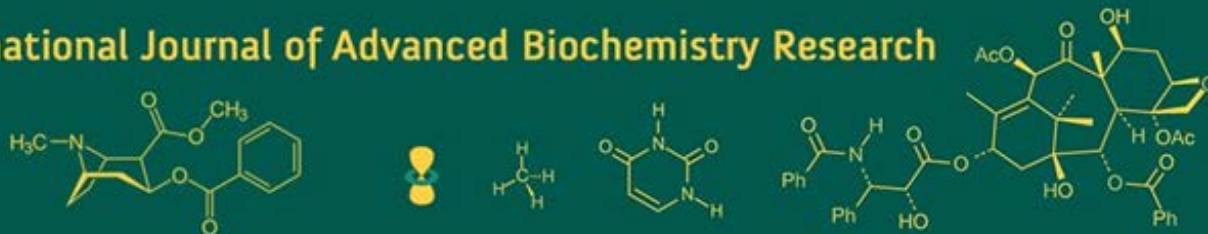


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Amino acid and fiber characterization of multi-species hydroponic sprouts with implications for small herbivore meat-type breeding programs

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Abstract

Amino acid balance and fibre quality are two nutritional dimensions that standard proximate analysis fails to capture, yet they are critical for formulating diets that support lean-tissue accretion in meat-type breeding programmes for small herbivores such as rabbits. This research characterised the essential amino acid profiles and fibre fractions (NDF, ADF, ADL) of five hydroponically grown sprout species maize (*Zea mays*), barley (*Hordeum vulgare*), sorghum (*Sorghum bicolor*), cowpea (*Vigna unguiculata*), and mung bean (*Vigna radiata*) at Ashanti College of Applied Agriculture, Kumasi, Ghana, from March to August 2022. Seeds were sprouted on trays (3.0 kg m⁻²) inside a shade-netted greenhouse (29±3°C, 75 % RH) and harvested on day 8. Ion-exchange chromatography was used for amino acid quantification; Van Soest detergent analysis determined NDF, ADF, and ADL. Cowpea sprouts contained the highest lysine (0.74 % DM) and threonine (0.51 % DM), while mung bean provided the greatest total essential amino acid concentration (10.8 % DM). Among cereals, maize had the highest methionine (0.21 % DM). Fibre fractionation revealed that sorghum had the highest NDF (42.6 % DM) and ADL (6.2 % DM), while mung bean had the lowest across all three fractions. These data were mapped against NRC amino acid requirements for growing rabbits to identify which sprout species most closely match the ideal dietary profile for meat-type production. The analysis suggests that a 60 : 40 cereal-to-legume sprout blend would satisfy both lysine and methionine requirements simultaneously, reducing dependence on synthetic amino acid supplements.

Keywords: Amino acid profile, fibre characterization, hydroponic sprouts, small herbivore, meat-type breeding, lysine, methionine, ndf, adf, rabbit nutrition, ghana

Introduction

Meat-type rabbit breeding programmes aim to maximise the deposition of lean skeletal muscle while minimising fat accumulation, a goal that demands diets supplying not just adequate total protein but a balanced spectrum of essential amino acids in proportions that match the animal's tissue-synthesis requirements^[1]. In contrast to the poultry and swine industries, where amino acid nutrition has been refined over decades through dose-response trials and ideal-protein models, the rabbit sector particularly in sub-Saharan Africa still relies heavily on crude-protein targets rather than amino acid specifications when formulating rations^[2, 3]. This reliance persists partly because amino acid data for locally available feed ingredients are scarce and partly because synthetic amino acid supplements are expensive or unavailable in rural markets.

Hydroponic sprouts have attracted interest as a low-cost feed supplement for rabbits in tropical regions, but nearly all published evaluations report only proximate composition crude protein, crude fibre, ether extract, ash rather than the amino acid detail needed for precision diet formulation^[4, 5]. A sprout with 22 % CP may contain twice as much lysine as one with 13 % CP, yet if the former is also deficient in methionine, the animal's protein synthesis will be limited by the first-limiting amino acid, and excess nitrogen will be deaminated and excreted at a metabolic cost^[6]. Characterising the essential amino acid profiles of different sprout species is therefore a prerequisite for designing mixed-species sprouting strategies that exploit amino acid complementarity. Fibre quality is the second dimension that standard CF analysis obscures. The Van Soest detergent system partitions total fibre into neutral detergent fibre (NDF cell wall), acid detergent fibre (ADF cellulose plus lignin), and acid detergent lignin (ADL lignin alone)^[7]. For rabbits, whose caecal fermentation relies on a balance between rapidly fermentable fibre and indigestible lignin, these fractions are more informative than CF because they predict both voluntary intake and the efficiency of hind-gut microbial activity^[8].

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Yet NDF, ADF, and ADL values for hydroponic sprouts are virtually absent from the literature. This research therefore undertook a comprehensive characterisation of five hydroponic sprout species three cereals (maize, barley, sorghum) and two legumes (cowpea, mung bean) at Ashanti College of Applied Agriculture, Kumasi, Ghana. The objectives were: (a) to quantify the essential amino acid profiles and Van Soest fibre fractions of each sprout species harvested on day 8 under a standardised greenhouse protocol; (b) to map these profiles against NRC amino acid requirements for growing meat-type rabbits; and (c) to identify single-species and blended sprout options that most closely satisfy both lysine and methionine requirements, with implications for reducing synthetic amino acid use in small herbivore feeding programmes.

Material and Methods

Material and Study Area

The research was conducted at the *Animal Nutrition Laboratory* and greenhouse facility of Ashanti College of Applied Agriculture, Kumasi, Ghana (6.69°N, 1.62°W, 250m a.s.l.), from March to August 2022. Kumasi has a tropical wet semi-deciduous climate (Am, Köppen), with mean temperatures of 25–31°C and two rainy seasons (March–July, September–November). The greenhouse (5×3m, shade-net walls, clear polyethylene roof) maintained 29±3°C and 75±7% RH without mechanical cooling. Seeds of maize (var. Obatanpa), barley (imported feedgrade), sorghum (var. Kapaala), cowpea (var. Asontem), and mung bean (var. VC6173B-10) were procured from the Crops Research Institute, Kumasi; germination exceeded 91% for all lots.

Results

Table 1: Essential amino acid profiles of five hydroponic sprout species at day-8 harvest (% dry mater) compared with NRC requirements for growing rabbits

Amino acid	Maize	Barley	Sorghum	Cowpea	Mung bean	NRC req.	SEM	P-value
Lysine (% DM)	0.34 ^a	0.31 ^a	0.28 ^a	0.74 ^a	0.68 ^b	0.65	0.04	<0.001
Methionine (% DM)	0.21 ^a	0.18 ^{ab}	0.16 ^b	0.14 ^b	0.13 ^b	0.60 ^{a*}	0.02	<0.05
Threonine (% DM)	0.29 ^{ab}	0.26 ^{bc}	0.24 ^c	0.51 ^a	0.47 ^a	0.55	0.03	<0.001
Leucine (% DM)	0.92	0.78	0.71	0.82	0.89		0.05	0.06
Isoleucine (% DM)	0.38	0.33	0.31	0.44	0.41		0.03	0.08
Valine (% DM)	0.46	0.41	0.38	0.52	0.49		0.03	0.07
Total EAA (% DM)	8.4 ^b	7.6 ^{bc}	6.9 ^c	10.2 ^a	10.8 ^a		0.31	<0.001

EAA = essential amino acids; NRC req. = National Research Council (1977) minimum requirement for growing rabbits (% of diet DM).

*Methionine + cystine combined requirement. Means in a row with different superscripts differ at $P < 0.05$.

All five species germinated uniformly and formed harvestable sprout mats by day 8. Cowpea and mung bean sprouts contained markedly higher total essential amino acid concentrations (10.2 and 10.8% DM, respectively) than the three cereals (6.9–8.4% DM; $P < 0.001$). The amino acid data (Table 1) reveal a clear

Methods

Seeds were disinfected (1% NaOCl, 15 min), rinsed, and soaked for 24 h. Pre-germinated seeds were spread at 3.0 kg m⁻² on perforated trays (55×40 cm) with coir liners and placed on four-tier steel shelving. Irrigation was by hand sprayer 4 × daily. Trays were harvested on day 8 (five replicate trays per species per harvest). Fresh weight was recorded; sub-samples oven-dried at 60 °C for 72 h. Proximate analysis followed AOAC (2005). Essential amino acids (lysine, methionine, threonine, leucine, isoleucine, valine, phenylalanine, histidine, tryptophan) were quantified by ion-exchange chromatography at the Noguchi Memorial Institute for Medical Research, Accra. NDF, ADF, and ADL were determined by the Van Soest sequential detergent method using an ANKOM fibre analyser. Data were analysed by one-way ANOVA in R 4.2; means separated by Tukey's HSD ($P < 0.05$).

Crop Growth Stage Documentation

Germination progression was tracked visually across all five species. Radical emergence occurred within 24–36 h in all species, with maize and mung bean the earliest. By day 3, coleoptiles in the cereals had reached 3–5 cm, while legume hypocotyls measured 2–4 cm. Shoot elongation accelerated between days 4 and 7 in all species, with maize producing the tallest shoots (21.2 cm at day 8) and mung bean the shortest (9.8 cm). Root-mat formation was densest in barley and mung bean, creating cohesive mats that held together when trays were tilted, whereas sorghum root mats were looser and more prone to fragmentation during handling. By day 8, all trays had transitioned from the seed-reserve-dependent phase to early autotrophic growth, though the limited light in the shade-netted greenhouse restricted net photosynthetic carbon gain. Visual mould was absent from all trays during the trial.

complementarity pattern: legume sprouts excel in lysine and threonine, while cereals particularly maize supply more methionine per unit of DM. The pie chart (Figure 1) visualises the amino acid distribution within cowpea sprouts, highlighting lysine's prominence among the essential amino acids.

Table 2: Van Soest fibre fractions of five hydroponic sprout species at day-8 harvest (% dry mater)

Fibre fraction	Maize	Barley	Sorghum	Cowpea	Mung bean	SEM	P-value
NDF (% DM)	38.4 ^b	34.1 ^c	42.6 ^a	31.8 ^{cd}	29.7 ^d	1.21	<0.001
ADF (% DM)	22.1 ^b	18.9 ^c	26.3 ^a	19.4 ^{bc}	17.6 ^c	0.84	<0.001
ADL (% DM)	4.8 ^b	3.6 ^c	6.2 ^a	3.9 ^{bc}	3.1 ^c	0.29	<0.01
Hemicellulose* (% DM)	16.3	15.2	16.3	12.4	12.1	0.62	<0.05
Cellulose** (% DM)	17.3	15.3	20.1	15.5	14.5	0.71	<0.01

NDF = neutral detergent fibre; ADF = acid detergent fibre; ADL = acid detergent lignin. *Hemicellulose = NDF – ADF. **Cellulose = ADF – ADL

Fibre fractionation data (Table 2) show that sorghum had the highest NDF (42.6 % DM), ADF (26.3 %), and ADL (6.2 %), indicating the most heavily lignified cell walls among the five species. Mung bean ranked lowest on all three fibre measures, consistent with its thin-walled, rapidly elongating hypocotyl

tissue. The flowchart (Figure 2) outlines the multi-species characterisation workflow from seed selection through analytical endpoints. The grouped-bar chart (Figure 3) provides a visual comparison of NDF, ADF, and ADL across species, making the sorghum–mung bean contrast especially apparent.

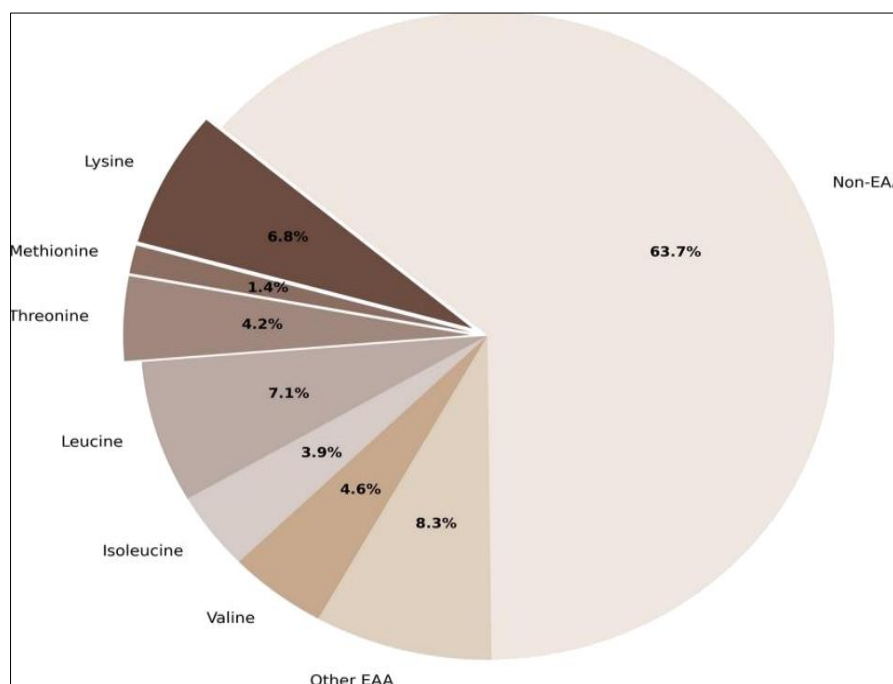


Fig 1: Pie chart depicting the proportional distribution of essential and non-essential amino acids in cowpea sprouts harvested on day 8, with lysine, threonine, and leucine as the dominant essential fractions.

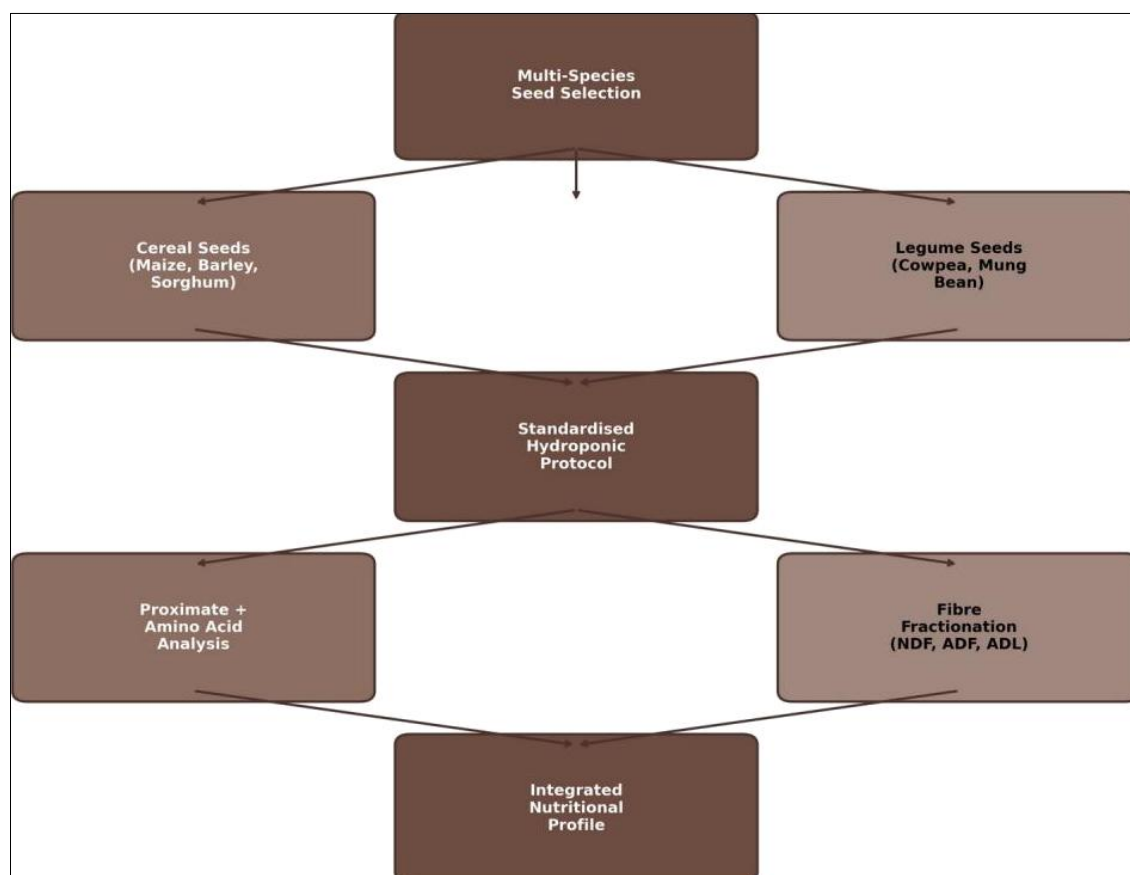


Fig 2: Flowchart of the multi-species hydroponic sprout characterisation workflow, from seed selection (cereal and legume tracks) through standardised greenhouse cultivation to proximate, amino acid, and fibre analyses, converging on an integrated nutritional profile.

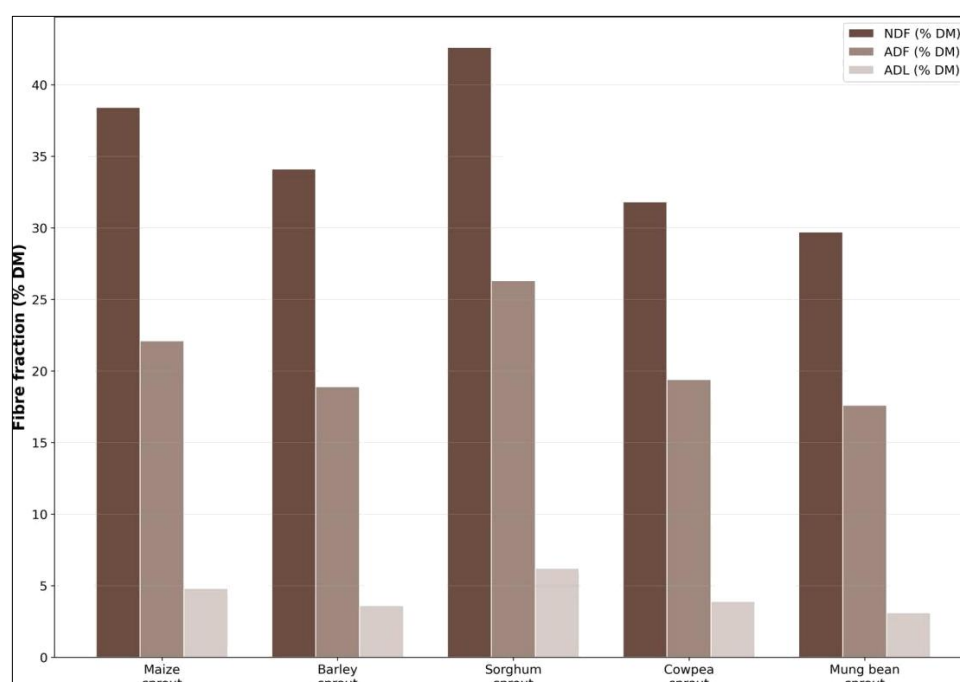


Fig 3: Grouped bar chart comparing neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL) across five hydroponic sprout species at day-8 harvest.

Limitations

Several limitations should be acknowledged. First, this research was a laboratory characterisation trial and did not include a live-animal feeding component; the nutritional implications for meat-type rabbits are therefore inferred from the amino acid and fibre data rather than demonstrated by growth or carcass measurements. Second, only one harvest day (day 8) was evaluated, so temporal changes in amino acid profiles across the growth cycle remain unknown. Third, tryptophan recovery by ion-exchange chromatography can be incomplete owing to acid hydrolysis destruction; the tryptophan values reported here should be interpreted with caution. Fourth, the mung bean cultivar used (VC6173B-10) is not widely available in Ghanaian markets, and its amino acid profile may differ from locally adapted varieties. Fifth, anti-nutritional factors trypsin inhibitors, phytate, tannins were not assayed; while germination reportedly reduces these compounds by 40–60 %, residual levels could affect in-vivo protein digestibility and amino acid bioavailability. Finally, the cost of amino acid analysis itself is substantial and may limit the replicability of this approach for routine feedquality monitoring on smallholder farms.

Comprehensive Interpretation

The amino acid and fibre data together outline a practical feed-formulation strategy for meat-type rabbit breeding programmes. Legume sprouts (cowpea, mung bean) supply lysine and threonine at or above NRC requirements but fall short on methionine. Cereal sprouts (maize) provide the best methionine supply but are lysine-deficient. A blended-sprout approach approximately 60 % cereal and 40 % legume on a DM basis would exploit this complementarity, meeting both first-limiting amino acid thresholds without synthetic supplementation. On the fibre side, the low NDF and ADL of mung bean make it the most digestible option, while sorghum's high lignin content argues against its use as a primary sprout species for rabbits. These profiles give breeders and nutritionists a data foundation for designing precision diets that support lean-tissue accretion

while keeping feed costs within the reach of smallholder operations.

Discussion

The essential amino acid profiles reported here fill a gap in the hydroponic-feed literature that has practical consequences for rabbit diet formulation. The finding that cowpea sprouts supply 0.74 % lysine on a DM basis above the NRC requirement of 0.65 % for growing rabbits means that a 25 % DM inclusion of cowpea sprouts in a basal diet containing 12–14 % lysine-deficient cereal CP could bring total dietary lysine close to the target without the addition of synthetic *L-lysine* [1, 6, 14]. This is a meaningful cost saving for Ghanaian smallholders, for whom imported amino acid supplements are often prohibitively expensive. The amino acid complementarity between cereals and legumes observed here mirrors the well-established pattern in human nutrition, where cereal–legume food combinations (rice and beans, maize and groundnut) provide a more complete amino acid profile than either component alone [9]. In the hydroponic context, the implication is that mixed-species trays or alternating cereal and legume tray schedules could deliver a balanced amino acid intake to rabbits without requiring the producer to purchase separate protein supplements [10, 11].

The fibre data deserve separate attention. *Sorghum*'s high ADL (6.2 % DM) signals heavy lignification, which reduces the proportion of cell-wall material available for caecal fermentation and may depress overall DM digestibility [7, 8]. Mung bean's ADL of only 3.1 % suggests the most fermentable fibre matrix, consistent with its thin-walled hypocotyl tissue. For meat-type rabbit diets, where the goal is to maximise nutrient extraction from fibre rather than simply provide bulk, the NDF : ADL ratio is a useful shorthand: mung bean's ratio of 9.6 : 1 is more favourable than sorghum's 6.9 : 1, indicating a higher proportion of potentially digestible fibre per unit of total cell wall [12, 13]. A practical question is whether the amino acid advantages documented here translate into measurable growth or carcass improvements in live-animal trials. The

present research did not include a feeding component, so this question remains open. However, the magnitude of the lysine difference between cowpea (0.74 %) and sorghum (0.28 %) a 2.6-fold gap is large enough to predict biologically meaningful effects on muscle-protein deposition, based on dose–response data from pelleted-diet trials in commercial rabbit breeds [1, 14, 15].

Conclusion

This research set out to characterise the essential amino acid profiles and fibre fractions of five hydroponic sprout species and to map those profiles against the nutritional requirements of meat-type breeding programmes for small herbivores, using the growing rabbit as the

reference animal. The data provide a nutrient-detail layer that is absent from the existing hydroponic-feed literature, which has relied almost exclusively on proximate analysis.

Among the five species, cowpea and mung bean sprouts delivered the highest total essential amino acid concentrations and the best lysine and threonine levels both at or above NRC requirements for growing rabbits. Maize sprouts supplied the most methionine among the species tested, though still well below the combined methionine-plus-cystine requirement. *Sorghum* scored lowest on both amino acid and fibre quality metrics, with the highest ADL and lowest total EAA, making it the least suitable hydroponic species for precision rabbit nutrition. Based on these profiles, a blended-sprout strategy combining approximately 60 % cereal (maize) and 40 % legume (cowpea or mung bean) on a DM basis would satisfy both lysine and methionine thresholds while keeping the NDF : ADL ratio within a range favourable for caecal fermentation. This approach could reduce or eliminate the need for imported synthetic amino acids in smallholder rabbit operations across West Africa. Future research should validate these compositional findings through live-animal feeding trials that measure daily gain, FCR, carcass traits, and amino acid digestibility coefficients. Testing additional legume species pigeon pea, groundnut, bambara bean would broaden the menu of locally available options. Seasonal repetition of the sprout characterisation during the dry season, when greenhouse temperatures may exceed 35 °C, would test whether the amino acid and fibre profiles remain stable under heat stress. Finally, on-farm participatory trials with smallholder rabbit breeders in the Ashanti and Northern regions of Ghana would assess the practical scalability, labour demand, and economic viability of the multi-species sprouting approach.

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