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# Effects of dietary forage on feed efficiency of poultry from a slow-growing and a dual-purpose strain for organic fattening systems

Florian Leiber <sup>a</sup>, Manuela Helbing<sup>a</sup>, Andrea K. Steiner<sup>a</sup>, Zivile Amsler<sup>a</sup>, Bettina Tonn <sup>a</sup>, Sergej L. Amelchanka<sup>b</sup>, Melissa Terranova <sup>b</sup> and Nele Quander-Stoll<sup>a</sup>

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## ABSTRACT

Dual-purpose chickens are increasingly used in European organic poultry systems. To test whether lower feed conversion efficiency of dual-purpose chickens could be counterbalanced by less intensive feeds with higher proportions of dietary fibre, a slow-growing conventional broiler genotype (Hubbard JA 757) was compared with a newly developed dual-purpose breed (Coffee ÖTZ), regarding their performance on diets with either low fibre (162 g kg<sup>-1</sup> NDF) and high protein (217 g kg<sup>-1</sup> CP; diet CON) or high fibre (256 g kg<sup>-1</sup> NDF) and low protein (188 g kg<sup>-1</sup> CP; diet EXT). In two further treatments, additionally to CON low- or high-quality chopped lucerne hay was offered separately. Forty-eight chicks of each genotype were allocated to the four treatments and fattened over 69 days (conventional broilers) or 77 days (dual-purpose roosters). After slaughter, intestinal organs and digesta were analysed. Voluntary intake of hay amounted to approximately 2% of the total feed eaten. In both genotypes, diet EXT led to higher intake and lower digestibility compared to CON, with less difference in Coffee. Genotype influenced feed intake, growth performance, dressing percentage, and carcass composition, all proving higher efficiency for Hubbard. Feed conversion efficiency was higher in Hubbard. However, in Coffee CP efficiency decreased less and energy efficiency even increased between CON and EXT. Gizzard, small intestine and caeca were larger, and fibre digestibility was higher in Coffee. Short-chain fatty acids in caecum were influenced by genotype. In conclusion, the high-fibre diet appeared suitable to reach appropriate protein and energy efficiency for Coffee roosters.

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Caecal fermentation; dietary fibre; dual-purpose chicken; extensive diet; extensive genotype

## Introduction

Organic poultry production systems aim to comply with several potentially conflicting goals at the same time. Based on the IFOAM principles of 'care' and 'health' (IFOAM 2024), animal welfare has a particularly important meaning. In national and organisational regulations, poultry welfare is addressed via prescription of space per animal, structures of the barns and access to outdoor runs, sometimes explicitly called pasture (Bio Suisse 2024; Leiber et al. 2024). Furthermore, extremes regarding genotypes and performance are avoided, for instance by defining a minimum length of fattening periods (European

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Commission 2018), for which slow growing broilers are needed. Recently, ethical considerations regarding the killing of 1-day-old male chicks from layer strains have led to increased use of dual-purpose breeds or fattening of layer cockerels.

On the other hand, the IFOAM principle of ‘ecology’ calls for sustainable resource utilisation, avoiding or reducing land-use changes and emissions into the atmosphere and biosphere. It is not always easy to reach all mentioned targets at once, as for instance large outdoor runs require more land and slowly growing genotypes, dual-purpose roosters or brother cockerels require more feed per unit of product (Ammer et al. 2017; Baldinger and Bussemas 2021; Kreuzer et al. 2020).

The recent prohibition of non-organic components along with the ban of added amino acids (European Commission 2018) makes it even more difficult in organic feeding to reach feed protein conversion rates comparable to conventional diets (Quander-Stoll et al. 2021). On the other hand, organic systems also aim for better utilisation of by-products for animal feed and a general reduction of food-grade feed components in animal production (Muller et al. 2017). Finally, the prescribed outdoor runs for organic chickens (European Commission 2018), provide them seasonally the opportunity to consume fresh forage (Hilimire 2012; Singh and Cowieson 2013), which may be voluntarily consumed by up to 20% of total dry matter intake (Leiber et al. 2024).

In the circumstances described above, the question emerges, whether less concentrated feeds for less specialised genotypes could be a match, leading to fattening systems that would be sustainable in themselves, although on lower levels of growth productivity. In that respect, roughage may partly serve as a valuable and appropriate feed component for organic broilers (Buchanan et al. 2007).

A specific property of the digestive tract in chickens could support extensive diets, which include higher proportions of dietary fibre: fibrous particles can be fermented in the caeca. Fermentation microbiota is supplied with nitrogen from urine, which is transported from the cloaca to the caeca by anti-peristaltic contractions (Clench and Mathias 1995; Svihus et al. 2013). Increased dietary fibre leads to increased caecal fermentation and even growth of the caeca in broiler chickens. Moreover, lower supply with dietary protein increases the rates of urea N conducted into the caeca (Svihus et al. 2013; Leiber et al. 2024). The results of caecal fermentation are short-chain fatty acids (Jozefiak et al. 2004), amino acids and ammonia, which can all be absorbed by epithelial villi of the proximal caeca (Moreto and Planas 1989) and serve as sources for energy and protein synthesis (Svihus et al. 2013). The hypothesis was deduced that a less extensive diet with higher proportions of fibrous material may increase protein and nitrogen utilisation and consequently compensate for lower efficiency and productivity of such diets and more extensive genotypes, like local breeds or dual-purpose chickens. Moreover, taking the animals’ behavioural, physiological and morphological abilities as main expressions of their species and therefore a basis for animal welfare definitions (Leiber et al. 2020), leads consequently to the acknowledgement that forage should be a required part of species appropriate diets for poultry, because of the digestive physiology and natural intake behaviour of the chicken.

With two dietary treatments, the hypothesis, whether protein efficiency in fattening broilers might benefit from fibrous feed components, was tested. A dual-purpose strain was compared with a conventional slow growing broiler strain across four dietary treatments with different shares, forms and qualities of roughage offer. Regarding genotype-feed interactions, the hypothesis was that the more extensive genotype (dual-purpose) would cope better with extensive (fibre-rich) feed and therefore an interaction of genotype and treatment would occur with regard to performance traits (Ammer et al. 2017).

The results of the study should generate knowledge to develop successful systems in which extensive genotypes are provided with fibre-rich feedstuffs and access to grazing for sustainable organic broiler production, addressing the challenges described above.

## Materials and methods

### Animals

This experiment took place from January until March 2022 at the research station AgroVet-Strickhof in Lindau, Switzerland. It was approved by the cantonal veterinary office of Zurich, Switzerland (ZH122/2021). Although the purpose of the study was to serve data for organic poultry systems, the experiment was conducted on a conventional research station in order to be able to calculate digestibility rates based on fully controlled intake and collection of excreta from the animal, since such a research unit under organic conditions was not available. The authors are aware of the related limitations with respect to ethics and direct applicability of the results to organic systems; however, this approach appeared justifiable in order to gain exact protein conversion data, which will help understanding the role of roughage in digestion of different genotypes and to base sustainability calculations on robust data.

Forty-eight 1-day-old broiler chicks (mixed sexes) of the slowly growing hybrid strain Hubbard JA 757 were purchased from Wüthrich Geflügel, Belp, Switzerland. This is a broiler hybrid well suited for a fattening period of at least 63 days as prescribed in organic regulations (European Commission 2018; Kreuzer et al. 2020; Bio Suisse 2024). Another 48 male rooster chicks of the dual-purpose strain Coffee (Ökologische Tierzucht gGmbH; Baldinger and Bussemas 2021; ÖTZ 2023) were purchased from Nina Griessmeier, Grüningen, Switzerland. Coffee is a crossbred of Bresse × New Hampshire, recently developed for the purposes of organic poultry systems with the aim to have a fair productivity and value of both the laying hen and the rooster (ÖTZ 2023). For the first 14 days, the chicks were kept in one group for each genotype at a farm in Grüningen, Switzerland in chick cages of 3 m<sup>2</sup> each, equipped with warming heaters, drinking troughs and feeders for ad libitum provision of water and certified chick starter feed for organic poultry (Crumbel Proflex 1401, Lehmann Bioprodukte AG, Gossau, Switzerland). From day 14 onwards, the chicks were housed at AgroVet-Strickhof pairwise in cages equipped for complete collection of faeces (excreta) and determination of intake (Heuel et al. 2022). The size of the cages was 0.6 m<sup>2</sup>, resulting in a stocking density of 3.3 birds m<sup>-2</sup>. The floor was soft plastic mesh. Half of the floor was covered by a mattress of artificial pvc grass, which was removed only during the phases when faeces were collected (every second week for 3 days). The cages were equipped with perches. The animals had always ad libitum access to three drinking nipples and feed (two troughs). From day 14 to day 28, the temperature was continuously reduced from 28°C to 22°C and was then maintained at 22°C thereafter. Cages were cleaned every day and at the same time the animals were visually observed for behaviour and health issues. For Hubbard animals, one male and one female were always placed together in one cage. In these cages, animals were raised until the pre-defined slaughter weight of 2000 g was reached, which was at day 69 for Hubbard and 77 for Coffee. The animals were slaughtered following all standards of the Swiss veterinary regulations for animal welfare.

### Feeds

Four different feed materials were used during the experiment; all purchased from Lehmann Bioprodukte AG, Gossau, Switzerland and certified organic. A control feed (CON), which was a standard organic broiler feed (trade name Poulet Crumbel 9–1500) was composed of soybean (*Glycine max*) cake, maize (*Zea mays*), wheat (*Triticum aestivum*), sunflower (*Helianthus annuus*) cake, wheat bran, triticale (*Triticosecale*), oats (*Avena sativa*), grass (*Lolium* spp.) and lucerne (*Medicago sativa*) meal, soybean oil and a mineral and vitamin premix. The targeted crude protein (CP) concentration was 22 g 100 g<sup>-1</sup> (as fed), and the crude fibre concentration was aspired at 3.5 g 100 g<sup>-1</sup> (as fed). A more extensive feed (EXT) was targeted at crude fibre concentrations of 8 g 100 g<sup>-1</sup> (as fed) and CP concentrations of 16 g 100 g<sup>-1</sup> (as fed) (trade name 9–2505 Extensiv Crumbel). Two lucerne hays differing in the content of CP (low CP: 'select-low', and high CP: 'select-high') were chopped in 1 cm length. The analysed nutrient composition of all feedstuffs is displayed in Table 1.

**Table 1.** Components and nutrient composition of the experimental feedstuffs ( $n = 4$ ).

	CON <sup>a</sup>	EXT <sup>a</sup>	SL <sup>a</sup>	SH <sup>a</sup>
Main components g 100 g <sup>-1</sup> as fed <sup>b</sup>				
Soybean cake	28.8	16.2	0	0
Maize	25.3	12.0	0	0
Wheat	10.0	11.5	0	0
Dried grass/lucerne	3.10	5.5	100	100
Wheat bran	5.0	29.9	0	0
DM (g 100 g <sup>-1</sup> as fed)	89.4 ± 0.20	89.6 ± 0.15	93.6 ± 0.15	92.0 ± 0.44
CA (g 100 g <sup>-1</sup> DM)	5.95 ± 0.05	8.15 ± 0.26	10.6 ± 0.06	9.35 ± 0.05
CP (g 100 g <sup>-1</sup> DM)	21.7 ± 0.30	18.8 ± 0.05	18.8 ± 0.10	21.1 ± 0.10
CF (g 100 g <sup>-1</sup> DM)	7.70 ± 0.06	6.05 ± 0.07	18.8 ± 0.70	24.5 ± 0.75
NDF <sup>d</sup> (g 100 g <sup>-1</sup> DM)	16.2 ± 0.3	25.6 ± 0.14	37.8 ± 0.15	40.5 ± 0.23
ADF <sup>d</sup> (g 100 g <sup>-1</sup> DM)	7.4 ± 0.41	10.7 ± 0.53	25.5 ± 0.22	30.1 ± 0.45
ADL <sup>d</sup> (g 100 g <sup>-1</sup> DM)	2.25 ± 0.05	2.60 ± 0.38	5.20 ± 0.09	8.15 ± 1.17
N-free extractive matter (g 100 g <sup>-1</sup> DM)	47.7 ± 0.30	49.1 ± 0.39	42.4 ± 0.63	35.1 ± 1.14
ME (MJ kg <sup>-1</sup> as fed)	11.9 ± 0.2	9.9 ± 0.3	n.a.	n.a.
Methionine (g 100 g <sup>-1</sup> as fed)	0.37 ± 0.04	0.28 ± 0.02	0.25 <sup>e</sup>	0.34 <sup>e</sup>
Lysine (g 100 g <sup>-1</sup> as fed)	1.14 ± 0.07	0.93 ± 0.07	0.71 <sup>e</sup>	0.79 <sup>e</sup>
Cysteine (g 100 g <sup>-1</sup> as fed)	0.36 <sup>e</sup>	0.31 <sup>e</sup>	0.14 <sup>e</sup>	0.26 <sup>e</sup>
Threonine (g 100 g <sup>-1</sup> as fed)	0.82 <sup>e</sup>	0.67 <sup>e</sup>	0.80 <sup>e</sup>	0.85 <sup>e</sup>

Notes: <sup>a</sup>CON, control standard feed; EXT, high fibre/low protein feed; SL, low-protein lucerne hay, which was offered additionally to CON in this group; SH, high-protein alfalfa hay, which was offered additionally to CON in this group. <sup>b</sup>as claimed by the producer. The remaining components of the diets are confidential property of the feed mill, but similar between CON and EXT. All Nutrients were analysed in duplicate; ME was calculated. <sup>c</sup>Standard deviations of the means (SD) are indicated with ±. <sup>d</sup>NDF, neutral detergent fibre, ADF, acid detergent fibre; ADL, acid detergent lignin. <sup>e</sup>only one sample analysed.

## Experimental design

The two above mentioned genotypes (Hubbard and Coffee) were allocated to four different feeding treatments: ad libitum supply with CON; ad libitum supply with EXT; ad libitum supply with CON plus ad libitum supply with select-low (SL); ad libitum supply with CON plus ad libitum supply with select-high<sup>7</sup> (SH). Per genotype and feeding treatment, six cages with two chicken each were allocated. This resulted in  $n = 12$  on animal level and  $n = 6$  on cage level per dietary treatment × genotype. In the Hubbard breed, the proportion of sexes was balanced between treatments. The low number of animals per cage was due to the available infrastructure, which had been developed with the Swiss veterinary authorities and is regularly used for broiler chicken experiments (Mueller et al. 2018; Kreuzer et al. 2020; Heuel et al. 2022).

## Data and sample collection

All animals were weighed and scored for injuries and plumage condition once weekly. Plumage was assessed at neck, abdomen, back, wings and tail, along with lesions at the head, integument, and footpads: all were rated on a scale, in which '4' indicated full integrity, '3' slight damages, '2' serious damages, and '1' complete lack of plumage, open wounds, or severely developed footpad abscesses, respectively (Tauson et al. 2005). Keel bone integrity was assessed against a four-step scale, with '4' indicating no pathological findings, through to '1' as a disintegrated fracture. Furthermore, lost claws were assessed. Gait was assessed according to a 5-level scale (Kestin et al. 1992) in which '0' signified symptomless walking, and '5' indicated inability to walk or stand.

Cumulated feed consumption was determined weekly on cage level, and all excreta were collected and weighed per cage (Heuel et al. 2022) every second week over 72 hours, respectively. The term 'excreta' has been used throughout the text, as urine and faeces could not be separated in the sampling. Representative samples from all feeds were taken two times during the experiment and analysed in duplicate. Feed and excreta samples were dried at 60°C for 24 h, milled to 1 mm particle size and stored in light-protected boxes at room temperature.

Body weights (BW) before slaughter and carcass weights (without head, neck, feet, feathers and viscera) were determined. Subsequently, breast muscle, legs and wings were prepared and weighed.

From the gastro-intestinal tract, gizzard, small intestine and caeca were opened and their complete contents were sampled and dried by lyophilisation, also as excreta. Due to very small samples, the digesta of, respectively, two cages (four animals) were pooled into one sample in order to have enough material for analyses. This resulted in  $n = 3$  per genotype  $\times$  treatment for digesta from the small intestine and caeca.

### Laboratory analyses

Feed samples were analysed for dry matter (DM), crude ash (CA), crude protein (CP), crude fat (CF), neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), N-free extractables, and amino acids according to European standard methods (BVL Bundesamt für Verbraucherschutz und Lebensmittelsicherheit 2019). Accordingly, the concentration of metabolisable energy (ME) was calculated. Samples of excreta and digesta of the small intestine and caeca were analysed in triplicate for DM and CA by heating to 105°C and 550°C, CP ( $N \times 6.25$ ) by elementary analysis, and ADF on a Fibertech 2020 (FOSS, Höganäs). All analytical methods for excreta and digesta are described in Leiber et al. (2004). Short-chain fatty acids (SCFA) were analysed in digesta from caeca on HPLC, following the procedure described by Amelchanka et al. (2010).

### Calculations and statistical analyses

The following calculations were carried out before statistical analysis:

$$\text{Digestibility rate DM} = (\text{DM intake}(\text{gd}^{-1}) - \text{DM faeces}(\text{gd}^{-1}))/\text{DM intake}(\text{gd}^{-1}) \quad (1)$$

$$\text{Digestibility rate CP} = (\text{CP intake}(\text{gd}^{-1}) - \text{CP faeces}(\text{gd}^{-1}))/\text{CP intake}(\text{gd}^{-1}) \quad (2)$$

$$\text{Digestibility rate ADF} = (\text{ADF intake}(\text{gd}^{-1}) - \text{ADF faeces}(\text{gd}^{-1}))/\text{ADF intake}(\text{gd}^{-1}) \quad (3)$$

$$\text{FeedconversionratioDM}(\text{FCR}_{\text{DM}}) = \text{TotalDMintakeanimal}^{-1}(\text{kg})/\text{carcassweight}(\text{kg}) \quad (4)$$

$$\text{Nutrient conversion ratio}(\text{NCR}_{\text{CP}}) = \text{Total CP intake animal}^{-1}(\text{kg})/\text{carcass weight}(\text{kg}) \quad (5)$$

$$\text{Feed utilisation ratio}(\text{FUR}_{\text{wheat}}) = \text{Total wheat intake animal}^{-1}(\text{kg})/\text{carcass weight}(\text{kg}), \quad (6)$$

where DM was dry matter, CP was crude protein, ADF was acid detergent fibre and d was day. NCR (5) was equally applied to metabolisable energy (MJ), methionine, and lysine; FUR (6) was equally applied to soybean cake, maize, and grass-lucerne meal (all in kg).

Statistical analyses were conducted using R. Studio (R Core Team 2023). Packages used were tidyverse, table1 and RColorBrewer. Variables were analysed using a two-way ANOVA with genotype and treatment as fixed effects, once separately and once as interaction. Where possible, the unit was the individual animal. In all variables involving intake, the unit was cage. Furthermore, a Tukey HSD test was performed post hoc.

## Results

Plumage, skin and keel bone integrity, as well as normal motoric behaviour were almost always on a high level. Among Coffee, three animals had slight injuries at the head, respectively two animals

had slight plumage disorders in the neck and at one wing, and one animal suffered from a medium footpad lesion and swelling during the last assessment before slaughter. Among Hubbard, one animal had a slight footpad lesion. For all other animals, no disorders were detected at all. Mortality was zero.

Feed intake was always higher with Coffee than with Hubbard (Figure 1(a); Table 2). For both genotypes, intake was highest in treatment EXT, and no differences were found between the other treatments. The average daily voluntary DM intake of roughage by Coffee broilers was 1.46 g in SL and 1.69 g in SH. Hubbard animals voluntarily consumed per day 1.58 of roughage in SL and 1.86 g in SH. The high DM intake rates in EXT groups of both genotypes, even led to slightly higher CP intake towards the end of the experiment (Figure 2(a)). Compared to CON, grass-lucerne intake was far higher in EXT and only slightly higher in SL and SH (Table 2), the latter more in the first half of the fattening period than in the second (Figure 3(a)).

Digestibility of DM was similar in both genotypes, however, with more temporal alterations in Hubbard (Figure 1(b)). Diet EXT had a poorer digestibility than CON, and since roughages were hardly consumed in SL and SH, no consistent differences between CON and the two selection treatments were found (Figure 1(b)). Digestibility of crude protein was poorer in EXT compared to that in the other treatments (Figure 2(b)). Also, for ADF, a poorer digestibility of EXT in both genotypes (Figure 3(b)) was found. However, digestibility of EXT (DM and ADF) constantly increased over time in Coffee, but not in Hubbard.

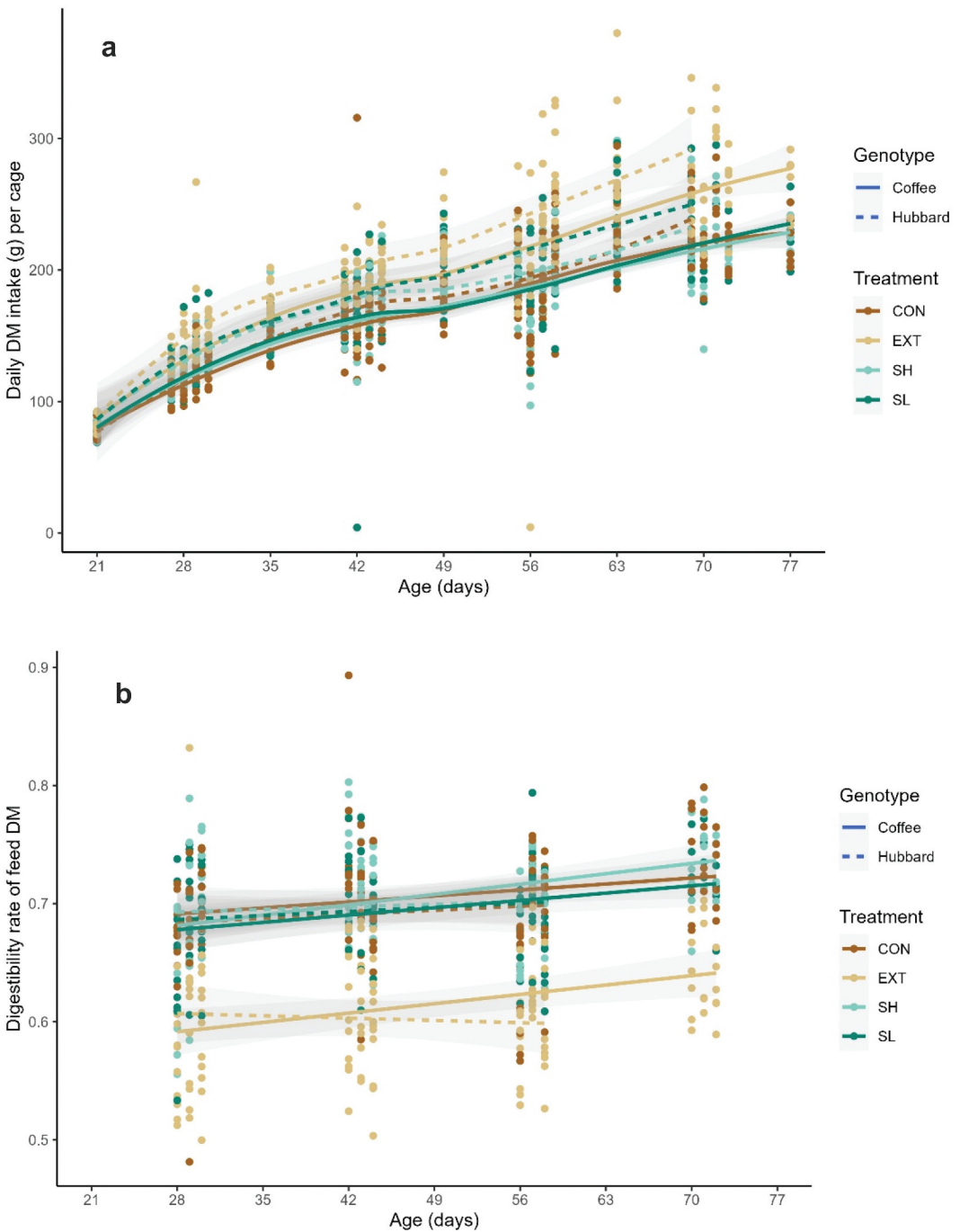
Weight development was steeper with Hubbard compared to Coffee broilers, and in both genotypes, SL animals grew faster than those from the other treatments (Figure 4). This resulted in numerically heavier BW (100–200 g) in SL at slaughter and carcass weights in both genotypes, though these differences were not statistically significant for the overall effects (Table 2). Average daily gain (ADG) was higher in Hubbard broilers by approximately 11%. Also, dressing percentage was higher in Hubbard.

A clear genotype effect led to smaller breast fillets in Coffee carcasses (Table 2). A treatment effect resulted in heavier breast fillets in SL (statistically significant in Hubbard), over the whole experiment. For drumsticks and wings weights no effects of genotype or treatment were found. However, the relative shares of the cuts from the whole carcass were affected by genotype: breast proportion was smaller, drumstick and wing proportions were higher in Coffee carcasses compared to Hubbard.

Dry matter feed conversion ratio (FCR) (kg feed per kg carcass weight) was clearly influenced by genotype (higher with Coffee in all treatments). The same was true for nutrient conversion ratio (NUE) and feed utilisation ratio (FUR; Table 3). Treatment affected conversion ratio for DM and CP (higher with EXT in both genotypes; Table 3). Metabolisable energy efficiency improved in Coffee from CON to EXT and was stable in Hubbard. Due to the composition of the main diets, EXT had a better conversion efficiency of soybean cake and maize, but lower for wheat in both genotypes. For all of the conversion efficiency traits, SH or SL were not different from CON.

Coffee animals had heavier gizzards, longer small intestine and longer caeca (Table 4). No effects of treatment on any of the measured parameters regarding the size of gastro-intestinal organs were found. Digesta from caeca contained less DM, but higher CP and ADF concentrations in Coffee compared to Hubbard (Table 5). Of the SCFA, lactate and butyrate were lower, and propionate was higher concentrated in the caecum digesta of Coffee broilers (Table 6). Butyrate production in the caeca of animals from the SL treatment was lower compared to the other treatments.

Excreta composition differed clearly between genotypes with higher values for DM, CP and ADF in Coffee broilers (Table 5). Higher DM, and lower CP as well as ADF were found in the excreta of the EXT treatment compared to all other.



**Figure 1.** (a) Daily dry matter (DM) intake in g per cage (= 2 animals). (b) Digestibility rate of feed DM per cage (= 2 animals). Dots represent the original datapoints, curves are fitted with `geom_smooth(ggplot2)` formula  $y \sim x$  (a) and linear fit (b), shadows represent confidence intervals. CON, control standard feed; EXT, high fibre/low protein feed; SL, low-protein lucerne hay separately offered plus CON; SH, high-protein lucerne hay separately offered plus CON.

**Table 2.** Feed intake, growth performance and carcass composition ( $n = 12$  animals per genotype  $G \times$  treatment  $T$ , if not stated differently).

Genotype	Coffee				Hubbard				SEM	<i>p</i> -values		
	CON	EXT	SH	SL	CON	EXT	SH	SL		G	T	$G \times T$
Feed treatment <sup>a</sup>												
Total feed intake (g DM animal <sup>-1</sup> ) <sup>b</sup>	5215b	6018a	5222b	5337b	4523c	5497b	4695c	4963c	186	<0.001	<0.001	ns
Total grass-lucerne intake (g DM animal <sup>-1</sup> ) <sup>b</sup>	162e	331a	257c	248c	140e	302b	233cd	227d	13.7	<0.05	<0.001	ns
BW at slaughter (g)	2050b	2040b	2110b	2140ab	2020b	2000b	2080b	2270a	115.8	ns	ns	ns
ADG (g day <sup>-1</sup> )	26.0b	25.9b	26.4b	26.8b	28.6ab	28.3ab	29.0ab	31.8a	0.95	<0.001	ns.	ns
Carcass weight without legs (g)	1130b	1130b	1170b	1180ab	1180ab	1150b	1190ab	1300a	71.6	ns.	ns	ns
Dressing percentage <sup>c</sup>	54.9b	55.2b	55.3b	55.1b	58.0a	57.4a	57.0a	57.2a	0.50	<0.001	ns	ns
Breast fillet weight (g)	243d	245d	264d	268cd	284bc	289b	292b	332a	16.1	<0.001	<0.01	ns
Drumstick weight (g)	421	419	433	441	407	390	408	457	27.5	ns	ns	ns
Wing weight (g)	122	121	125	125	122	120	125	139	6.8	ns	ns	ns
Breast fillet (%) <sup>d</sup>	21.5b	21.7b	22.6b	22.8ab	24.3ab	25.2a	24.9a	25.6a	0.41	<0.001	ns	ns
Drumstick (%) <sup>d</sup>	37.4a	37.1a	37.2a	37.5a	34.5b	33.8b	34.3b	35.0b	0.44	<0.001	ns	ns
Wing (%) <sup>d</sup>	10.9a	10.8a	10.8a	10.6ab	10.4c	10.4c	10.5bc	10.7ab	0.12	<0.01	ns	ns

Notes:<sup>a</sup>CON, control standard feed; EXT, high fibre/low protein feed; SL, low-protein alfalfa hay separately offered plus CON; SH, high-protein lucerne hay separately offered plus CON. <sup>b</sup> $n = 6$  cages per genotype $\times$ treatment interaction. <sup>c</sup>carcass weight percentage of BW. <sup>d</sup>weight percentage of carcass. Values in rows followed by different letters are significantly different. ns, not significant. BW, body weight; ADG, average daily gain.

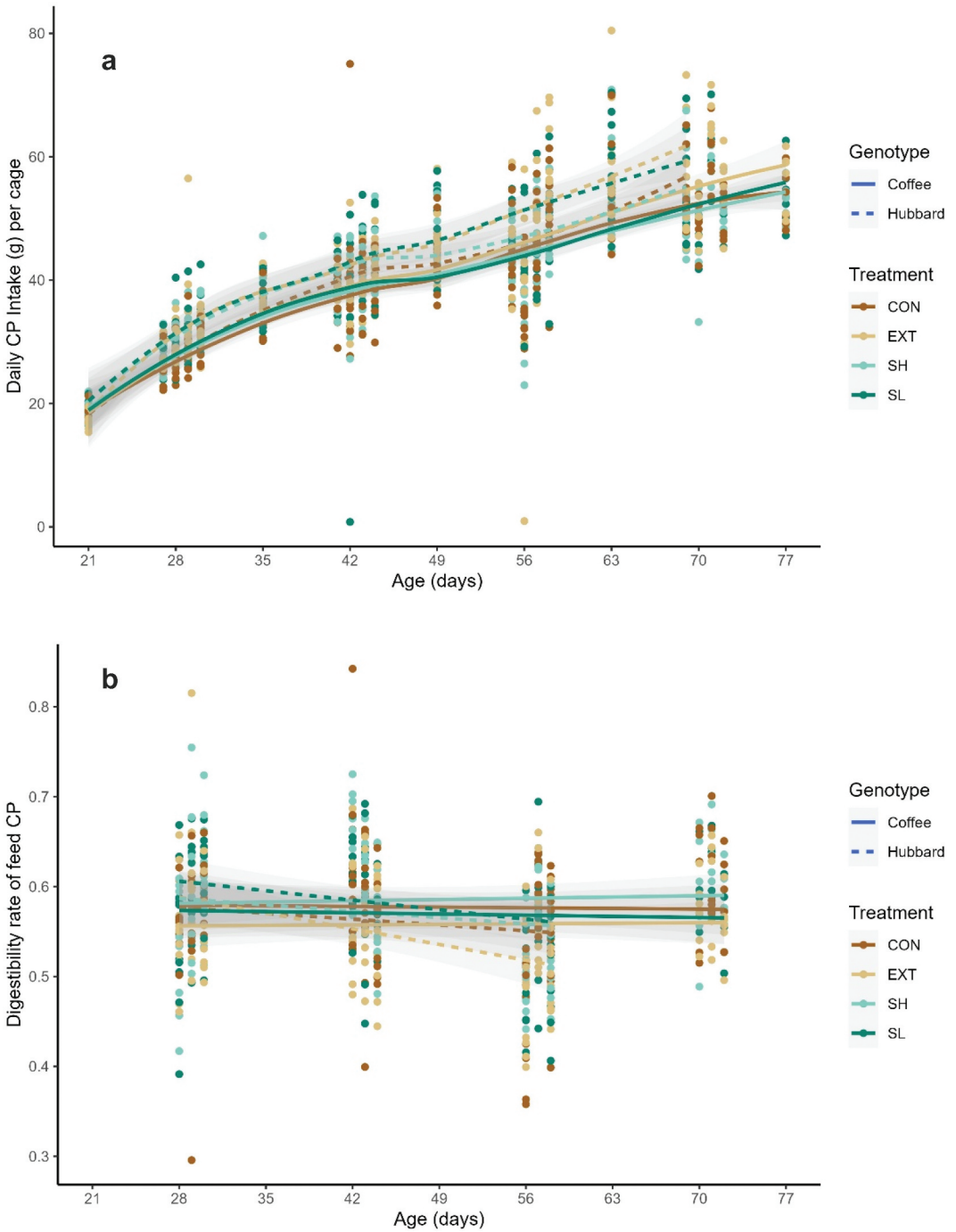
## Discussion

Species appropriateness of animal husbandry is an important pillar of welfare definitions in organic agriculture (Vaarst and Alrøe 2012; Wagner et al. 2021). This includes access to outdoor areas (Bioland 2024; Bio Suisse 2024) and appropriate feedstuff (Vaarst and Alrøe 2012; Leiber et al. 2020). For chickens, due to their digestive physiology (Svihus et al. 2013), roughage containing feed is a natural part of their diet and might be considered as a species appropriate necessity. Based on the physiological functions of chicken caeca (Clench and Mathias 1995; Svihus et al. 2013), the hypothesis for this study was that increased dietary fibre might stimulate caecal fermentation and thus increase re-incorporation of urinary N, resulting in better N utilisation. The clearly lower CP concentrations in faeces of animals in EXT compared to CON treatment indicated that the expected effect of higher dietary fibre occurred, thus confirming the significance of fibre digestion to chicken nitrogen efficiency.

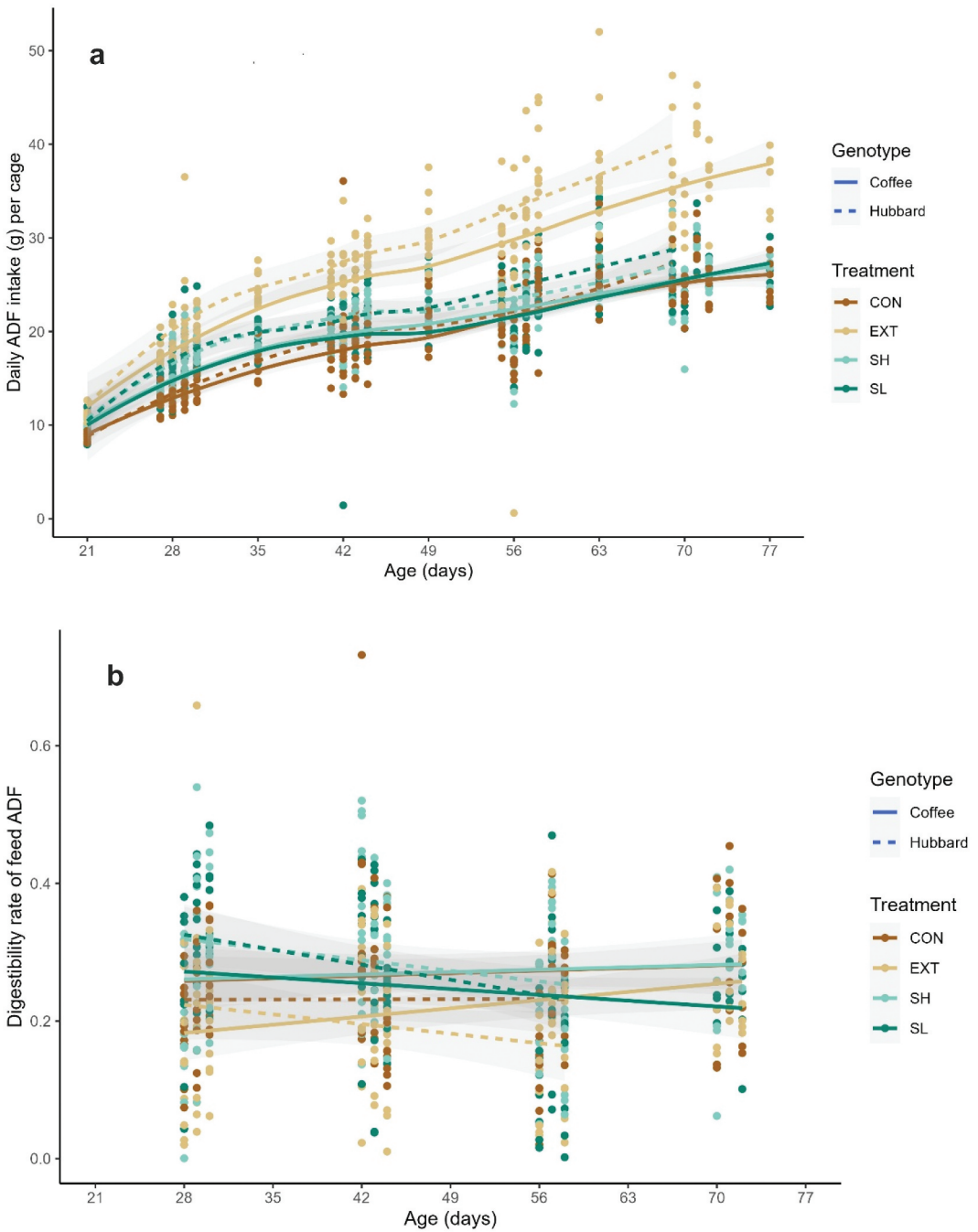
The rather low voluntary intake showed that dried forage was not the best option to offer fibre to the chickens, though. Pasture uptake has recently been shown to cover around 20% of the dietary requirements of layers (Leiber et al. 2024). This might have been a better option for broilers and roosters. Also, lucerne silage might have been more accepted (Carrasco et al. 2018).

## Genotype effects

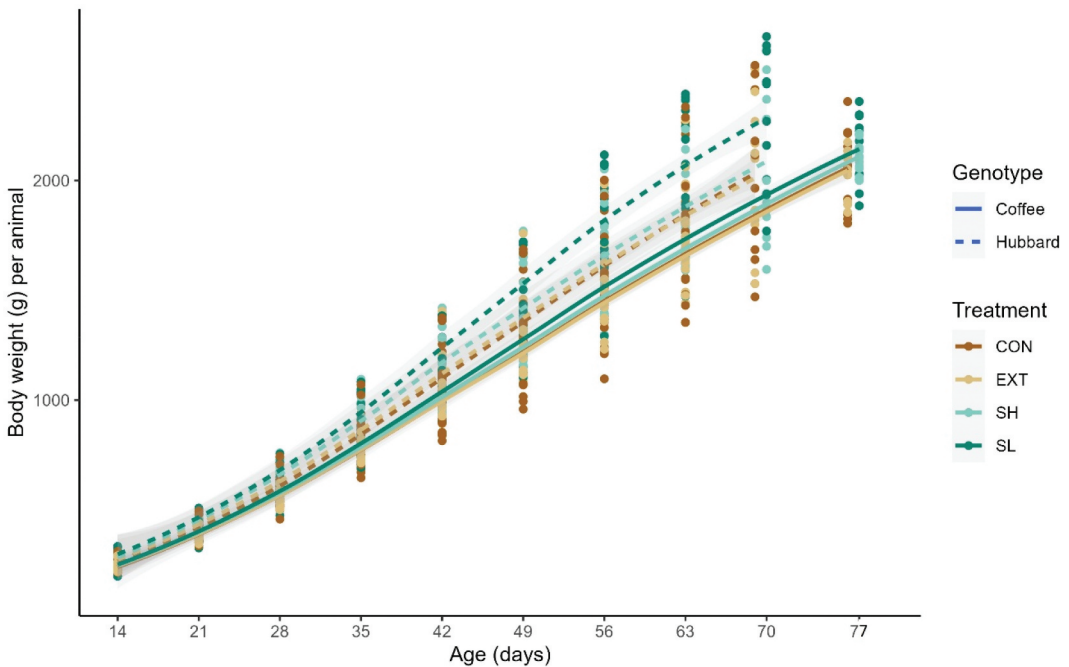
The current experiment aimed at investigating the effects of increased dietary fibre consumption on roosters of a single dual-purpose breed and broilers from a slow-growing fattening hybrid strain. Sexes (only male for Coffee and mixed for Hubbard) and age at slaughter differed between the two compared genotypes. However, this reflected exactly the practical systems these different genotypes are embedded in. In that sense, two systems were compared rather than two genotypes *sensu strictu*, as appropriate with respect to the practical relevance of the results. It had been hypothesised that there would occur an interaction of feed with genotype regarding performance (Ammer et al. 2017). Due to increasing demand for dual-purpose chickens for different reasons, particularly in organic



**Figure 2.** (a) Daily crude protein (CP) intake in g per cage (= 2 animals). (b) Digestibility rate of feed CP per cage (= 2 animals). Dots represent the original datapoints, curves are fitted with `geom_smooth(ggplot2)` formula =  $y \sim x$  (a) and linear fit (b), shadows represent confidence intervals. CON, control standard feed; EXT, high fibre/low protein feed; SL, low-protein lucerne hay separately offered plus CON; SH, high-protein lucerne hay separately offered plus CON.



**Figure 3.** (a) Daily ADF intake in g per cage (= 2 animals). (b) Digestibility rate of feed ADF per cage (= 2 animals). Dots represent the original datapoints, curves are fitted with `geom_smooth(ggplot2)` formula =  $y \sim x$  (a) and linear fit (b), shadows represent confidence intervals. CON, control standard feed; EXT, high fibre/low protein feed; SL, low-protein lucerne hay separately offered plus CON; SH, high-protein lucerne hay separately offered plus CON.



**Figure 4.** Body weight development in g per animal. Dots represent the original datapoints, curves are fitted with `geom_smooth` (`ggplot2`) formula =  $y \sim x$ , shadows represent confidence intervals. CON, control standard feed; EXT, high fibre/low protein feed; SL, low-protein lucerne hay separately offered plus CON; SH, high-protein lucerne hay separately offered plus CON.

**Table 3.** Feed conversion efficiency of nutrients and diet components ( $n = 6$  cages per genotype  $G \times$  treatment  $T$ ).

Genotype	Coffee				Hubbard				$p$ -values			
	CON	EXT	SH	SL	CON	EXT	SH	SL	SEM	G	T	$G \times T$
Feed treatment <sup>1</sup>												
FCR <sub>DM</sub> <sup>2</sup>	4.65c	5.35a	4.48c	4.54c	3.94d	4.81b	4.01d	3.85d	0.108	<0.001	<0.001	ns
NCR <sub>CP</sub> <sup>3</sup>	1.11a	1.13a	1.06ab	1.08a	0.94c	1.02b	0.95c	0.91c	0.038	<0.001	<0.01	ns
NCR <sub>ME</sub> <sup>4</sup>	54.0a	51.9b	51.4b	52.2b	45.7c	46.7c	46.0c	44.2c	1.19	<0.001	ns	ns
NCR <sub>Methionine</sub> <sup>3</sup>	0.017a	0.015b	0.017a	0.017a	0.015b	0.013c	0.015b	0.014c	0.000	<0.001	<0.001	ns
NCR <sub>Lysine</sub> <sup>3</sup>	0.053a	0.050a	0.051a	0.051a	0.045b	0.045b	0.045b	0.044b	0.001	<0.001	ns	ns
FUR <sub>soybean cake</sub> <sup>5</sup>	1.35a	0.87c	1.28a	1.29a	1.14b	0.78d	1.14b	1.10b	0.028	<0.001	<0.001	ns
FUR <sub>maize</sub> <sup>5</sup>	1.16a	0.64c	1.09a	1.12a	0.98b	0.58c	0.98b	0.95b	0.024	<0.001	<0.001	<0.1
FUR <sub>wheat</sub> <sup>5</sup>	0.47c	0.62a	0.44c	0.45c	0.39d	0.55b	0.39d	0.38d	0.011	<0.001	<0.001	ns
FUR <sub>grassmeal</sub> <sup>6</sup>	0.14d	0.29a	0.22c	0.21c	0.12e	0.26b	0.20c	0.18c	0.014	<0.05	<0.001	ns

Notes: FCR, Feed conversion ratio; NCR, Nutrient conversion ratio; FUR, Feed utilisation ratio <sup>1</sup>CON, control standard feed; EXT, high fibre/low protein feed; SL, low-protein lucerne hay separately offered plus CON; SH, high-protein lucerne hay separately offered plus CON. <sup>2</sup>kg DM feed intake per kg carcass weight. <sup>3</sup>kg intake of indicated nutrient per kg carcass weight. <sup>4</sup>MJ intake of metabolisable energy per kg carcass weight. <sup>5</sup>kg intake of indicated feed component per kg carcass weight. <sup>6</sup>kg grass-lucerne meal intake per kg carcass weight. Values in rows followed by different letters are significantly different. ns, not significant.

poultry production, the authors also aimed at direct comparison of a new dual-purpose strain with a classical hybrid strain for broiler fattening.

It has been well established that broilers from dual-purpose strains show lower growth rates than classical fattening hybrids (Mueller et al. 2018; Tiemann et al. 2020). However, basic performance comparisons are necessary for each new strain that is going to be introduced to the market. This is currently the case for the dual-purpose strain Coffee (Ökologische Tierzucht gGmbH; ÖTZ 2023), which is newly available in Germany and Switzerland, for what reason it was compared to Hubbard JA 757. The BW at slaughter was equal for both genotypes due to the fact that slaughter for each respective genotype took place, when they had reached

**Table 4.** Sizes of fractions of the gastrointestinal tract ( $n = 6$  animals per genotype  $G \times$  treatment  $T$ ).

Genotype	Coffee				Hubbard				SEM	$p$ -values		
	CON	EXT	SH	SL	CON	EXT	SH	SL		G	T	$G \times T$
Feeding treatment <sup>1</sup>												
Crop weight empty (g)	4.95	5.02	5.20	4.84	5.16	5.32	5.33	4.92	0.325	ns	ns	ns
Gizzard weight empty (g)	49.4a	48.1b	51.7a	50.7a	48.3b	47.2bc	48.8b	45.1c	1.65	<0.05	ns	ns
Small intestine length (cm)	140b	151a	145a	148a	134c	137c	135c	143b	4.11	<0.01	ns	ns
Caeca length (cm)	17.3b	18.9a	18.0a	18.1a	16.3c	16.5c	17.1b	17.8b	0.50	<0.01	ns	ns
Caeca weight empty (g)	5.86	7.12	6.78	6.34	7.07	7.04	6.80	6.46	0.351	ns	ns	ns

Notes: <sup>1</sup>CON, control standard feed; EXT, high fibre/low protein feed; SL, low-protein lucerne hay separately offered plus CON; SH, high-protein lucerne hay separately offered plus CON. Values in rows followed by different letters are significantly different. ns, not significant.

**Table 5.** Mass and composition of digesta from caeca and excreta.

Genotype	Coffee				Hubbard				SEM	$p$ -values		
	CON	EXT	SH	SL	CON	EXT	SH	SL		G	T	$G \times T$
Feeding treatment <sup>1</sup>												
<b>Caecal digesta</b> ( $n = 3$ for genotype $\times$ treatment; pools from 4 animals each)												
FM g	7.61	8.07	7.78	8.23	6.90	6.85	8.55	7.56	0.730	ns	ns	ns
DM g 100 g <sup>-1</sup> FM	22.0c	21.7c	23.2b	23.0b	23.2b	25.8a	22.7b	24.9a	1.07	<0.01	<0.05	<0.05
CP g 100 g <sup>-1</sup> DM	60.0a	59.1a	59.8a	60.1a	57.5b	59.6a	57.6b	59.3a	1.58	<0.05	ns	ns
ADF g 100 g <sup>-1</sup> DM	1.52bc	1.48c	1.79b	2.15a	1.06e	1.47c	0.91e	1.21d	0.295	<0.001	<0.05	<0.01
<b>Excreta</b> ( $n = 48$ samples on cage basis)												
DM g 100 g <sup>-1</sup> FM	37.8d	42.6a	41.5b	39.9c	36.7e	40.9bc	36.6e	34.5f	0.41	<0.001	<0.001	0.01
CP g 100 g <sup>-1</sup> DM	35.9a	25.3d	35.8a	35.5ab	35.1b	25.7d	35.3b	34.4c	0.24	<0.05	<0.001	ns
ADF g 100 g <sup>-1</sup> DM	30.5c	28.1f	31.9a	31.2b	30.0c	28.8e	29.5d	29.0de	0.13	<0.001	<0.001	<0.001

Notes: <sup>1</sup>CON, control standard feed; EXT, high fibre/low protein feed; SL, low-protein lucerne hay separately offered plus CON; SH, high-protein lucerne hay separately offered plus CON. FM, fresh matter; DM, dry matter; CP, crude protein; ADF, acid detergent fibre. Values in rows followed by different letters are significantly different. ns, not significant.

**Table 6.** Short-chain fatty acids in caeca contents ( $\mu\text{mol g}^{-1}$ ;  $n = 3$ ; pools from 4 animals each).

Genotype	Coffee				Hubbard				SEM	$p$ -values		
	CON	EXT	SH	SL	CON	EXT	SH	SL		G	T	$G \times T$
Feeding treatment <sup>1</sup>												
Lactate	8.29f	8.84ef	10.3bc	9.27de	10.9ab	10.0bc	11.1a	9.60cd	0.472	<0.001	ns	<0.05
Acetate	76.4	85.8	65.9	46.2	82.7	60.0	55.4	65.7	11.60	ns	ns	ns
Propionate	4.72b	6.28a	5.35b	4.58b	3.09c	2.64c	2.69c	4.91b	0.436	<0.001	ns	<0.01
Butyrate	9.77b	8.5c	9.08b	7.96c	11.4a	11.6a	11.5a	9.62b	0.402	<0.001	<0.01	ns
Total	99.1	109	90.7	68.1	108	84.7	79.6	91.4	11.93	ns	ns	ns

Notes: <sup>1</sup>CON, control standard feed; EXT, high fibre/low protein feed; SL, low-protein lucerne hay separately offered plus CON; SH, high-protein lucerne hay separately offered plus CON. Values in rows followed by different letters are significantly different. ns, not significant.

approximately 2000 g. The reason that average daily gain of Coffee broilers was 11% lower over the whole growing period, was that they grew slower and needed 8 days more to reach the predefined slaughter weight. These growth curves for Coffee were well in the range of known performances of traditional dual-purpose breeds (Belgian Malines and Schweizerhuhn; Mueller et al. 2018).

The lower dressing percentage of Coffee corresponded with the absolute larger size of the gizzard, small intestines and caeca. Also, composition of carcass fitted into the picture of the study from Mueller et al. (2018), with smaller breast and larger leg proportions in Coffee compared to Hubbard. Thus, clear developmental and morphological differences were found as well in the body as in the gastro-intestinal tract between the genotypes, which makes Coffee broilers less meat pronounced than Hubbard, which is trivially caused by a different selection history with strong focus on breast muscle in the high performing genotypes

(Emmerson 2003). Notably, other than expected, the larger intestines were not related to daily intake rates.

Regarding feed conversion ratio, Coffee broilers performed similarly to slow-growing broilers in other studies (Koreleski and Swiatkiewicz 2008; Leiber et al. 2017). However, the higher (less efficient) feed conversion ratio on DM and on CP basis in dual-purpose chicken compared to industrial genotypes was in the range of the expected (Mueller et al. 2018; Chodova et al. 2021; Baldinger and Bussemas 2021) and remains one of the challenges regarding the ecological and economic sustainability of dual-purpose poultry breeds.

### **Treatment effects**

The main finding was that under the conditions of the current experiment, the voluntary intake of roughage was lower than expected (Ponte et al. 2008; Singh and Cowieson 2013). This might have been partly due to poor palatability of the hay for broilers (Valeckova et al. 2020) and lack of experience of the young chicks. In consequence, the treatments SL and SH were effectively similar to CON, and the main contrast was found between CON and EXT. A higher final body weight of Hubbard in SL compared to CON was significant. However, this result was accompanied and explained by a significant higher total feed intake in this specific group. Animals in EXT treatments compensated for lower digestibility with higher feed intake, which resulted in similar growth performance and carcass composition compared to the other treatments. One of the most interesting interactions of genotype and treatment occurred with the feed and nutrient conversion ratios. Animals fed with EXT had a greater FCR for DM and NCR for CP than those fed CON. However, this difference between EXT and CON was smaller with Coffee than with Hubbard. For ME, Coffee even showed improved efficiency with EXT compared to CON, in contrast to Hubbard, where dietary treatment had no effect on energy efficiency. This slight but evident advantage of less efficient genotypes when supplied with extensive diets was in line with earlier reports (Ammer et al. 2017; Chodova et al. 2021). Together with increasing digestibility of EXT in Coffee during the fattening period, the implication of this finding was that relative to CON treatments as a basis, the less intensive genotype coped better with EXT than Hubbard did. Hence, a somewhat less intensive diet might be fed to less extensive broiler genotypes without losing performance and efficiency. This might offer a strategy for a reduction of nutrient waste.

The current study did not integrate differentiated feeding phases. Reduction of feed CP in the last weeks of the fattening period clearly have potential to improve nutrient efficiency; however, this was not applied according to regional practice in Switzerland.

Feed effects on the size of gizzard (Valeckova et al. 2020) and caeca (Svihus et al. 2013), had been expected but did not occur. Based on the literature (Jozefiak et al. 2004; Rehman et al. 2008; Svihus et al. 2013) it had been expected that the differences in fibre supply would affect caecal fermentation, including the production of SCFA. No effects on nutrient composition in the caecal digesta occurred and the only treatment effect on SCFA composition was a reduced presence of butyrate in SL groups of both genotypes. Butyrate formation is related to different bacteria, in particular *Faecalibacterium prausnitzii* (Svihus et al. 2013; Ali et al. 2022), which ferment mono- and oligosaccharides. Butyrate formation was reported to be positively related to excreta DM in poultry (Such et al. 2021) and the same association was found in the current study.

Important treatment effects were found in excreta. The considerably lower protein content in excreta from EXT may indicate increased anti-peristaltic uptake of urine into caeca (Clench and Mathias 1995; Svihus et al. 2013). This implied that the apparent digestibility of CP was biased by re-utilisation of urine, which explained the lack of difference between CON and EXT regarding this variable. Nonetheless, better urine-N utilisation, which was also reported by Such et al. (2021) for fibrous diets, has the potential to reduce ammonia-N emissions into the environment.

The results indicated, if any, just a very small step towards solution of the conflicts of interest and trade-offs between the goals of resource efficiency, land-use issues and avoidance of feed-food

competition on the one hand and animal welfare, especially species-appropriateness, on the other. The combination of less extensive animals with diets containing less protein and more fibre, as was evaluated in the current and in other studies, contribute only a small step towards a solution (Mueller et al. 2018; Kreuzer et al. 2020). Reducing animal numbers on farms and meat volumes on plates, is without doubt a prerequisite for organic agriculture to realise its values and benefits (Muller et al. 2017) and create opportunity for high ethical standards on all levels. The four IFOAM principles of organic agriculture (health, fairness, ecology and care; IFOAM 2024) may need to be complemented with a fifth principle of ‘sufficiency’ to foster awareness about the necessity of reducing animal numbers and production volumes in order to reach the original four.

## Conclusions

Significant breed differences were found between Hubbard broilers and Coffee roosters regarding total feed intake, growth performance, dressing percentage, and feed conversion. Hubbard broilers were more efficient, because they needed less feed and time to reach the same body weight compared to Coffee. A core question of the experiment was whether the extensive genotype would cope better with extensive feed. This held true especially for efficiency of metabolisable energy, but was not sufficiently pronounced to fully counteract the generally lower resource conversion of the Coffee roosters. However, in the light of ecological and economic resource costs, welfare requirements of species appropriate feeding and an improved energy efficiency of Coffee roosters with the extensive diet, several arguments from the current study were in favour of, and none against, using less concentrated feeds for fattening dual-purpose chicken.

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