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Poultry Biodiversity for Alternative Farming Systems Development

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Abstract. Poultry biodiversity represents a key factor to improve poultry resilience and promote sustainable and low input farming systems. The EU and member states promote protection of livestock biodiversity and the development of alternative farming through funding projects such as “Local Chicken Breeds in Alternative Production Chain: Welfare, Quality and Sustainability”. The aim of the present research was to identify between five different poultry genotypes, Bionda Piemontese (BP), Robusta Maculata (RM), RM x Sasso (RMxS), BP x Sasso (BPxS) and a commercial hybrid (Ross 308) the best suitable breed in terms of productivity and welfare for alternative housing system. A total of 300, 21 days old male birds were randomly allotted in two housing systems (industrial, controlled environment, 33 kg/m² and standard diet and free-range, natural environmental conditions, 21 kg/m², access to outdoor area and low-input diet. Slaughtering was performed at 42 days of age at for industrial Ross and at 81 days of age for other genotypes and free-range Ross and productive performance and behavioural analysis were evaluated. Effect of housing system, genotype and their interaction were significant for many studied parameters, showing broiler not the ideal genotype for extensive farming system, which is more suited for low/medium performance strains.

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1 Introduction

Humans are in continuous expansion, as FAO states, by 2050 global population will reach 10 billion people and, with this constant population increase, the consumption of food from animal origin will increase dramatically. It will be necessary to increase the number of farmed animals and implement new ways of farming.

Traditional farming system is already not considered sustainable, and the situation will worsen every year. The main phenomena related to intensive farming are deforestation, greenhouse gasses emissions, excessive consumption and pollution of land and water [1]. Another side effect of this industrialization process is the reduction of genetic variability and the consequent vulnerability of animals to environmental stress [2].

Poultry farming has a lower environmental impact than other animal production chains thanks to the high efficiency in converting feed into eggs and meat. The shorter production cycle and the strong genetic selection carried out to increase production performance represent an advantage over ruminant or swine farming. This is particularly evident in the poultry meat industry, in fact, modern broilers reach slaughtering weights in short cycles of about 40 days with a high percentage of meat yield [3]. Unfortunately, in addition to all the benefits listed above these high-performance strains (HPS) show wellness and health issues, skeletal imbalances, metabolic disorders, and muscle abnormalities, which affect the appearance of the meat, nutritional traits, and acceptance by consumers [4, 5].

These are some of the main reasons why new sustainable ways of farming animals need to be identified. However, poultry meat and egg production rely on these HPSs presenting major animal health and welfare concerns [6]. As a result, there is a growing demand in developed countries for poultry meat and eggs from welfare-friendly farming systems [7]. Alternative poultry production is more expensive than intensive, but supports biodiversity, local economies and the multifunctionality of farms, providing eggs and meat to which a growing part of consumers attributes high ethical value, quality and taste [2].

Alternative systems (organic, biodynamics, free-range) require birds adapted to a not controlled environment, high foraging aptitude, immune response, and thermo-tolerance. The response of chickens to alternative systems and to different climatic conditions have not been sufficiently investigated and only few commercial breeds are available for these rearing systems, HPS, unlike Local Breeds (LB), are highly unsuited to this purpose [3].

Nowadays, the preservation of poultry biodiversity is a key objective in all developed countries [4]. The possibility of improving LB originates from the balance between the benefits (good health and welfare, resistance and resilience to health stress, lower dietary needs, less veterinary protection) and unfavourable aspects (low performance) [5]. Accordingly, an essential step is the improvement of production efficiency in LB. Crossbreeding is the main tool used in poultry, it normally involves a cross between HPS and LB, with the aim of combining the production capacity of the former with the latter's adaptability to a poor environment. Cross breeding also maximizes the expression of heterosis and normally improves fitness characteristics [6].

Moreover, since the current HPS are specialized in either meat or egg production and egg production requires only females, the male of egg-type strain, due to their slow-growth rate, are killed at 1 day-old. Ethical reasons exist against this practice and the use of dual-purpose breeds could be a solution to it: the males and the females of local breeds could be farmed for meat and eggs, respectively. An additional reason to safeguard LB derives from their ability to produce meat and eggs in alternative systems, with low-input diets and with outdoor run that produce meat and eggs with higher welfare standards [7]. These aspects meet the attitude of consumer, in developed countries such as Italy, who are becoming increasingly careful about the impact of food consumption choices where the consumers can make an opinionated decision about their meal taking in considerations animal welfare, sustainability,

nutritional, sensory, and ethical factors. It's obvious that, in most countries where poverty and hunger is rampant, HPS still represents a good opportunity to provide quite cheap high value food [14, 15]. Worldwide, industrial farming systems account for 67% of poultry meat production and 50% of eggs; an increase in local poultry farming is therefore feasible if supported by a productive and economic perspective [16]. The conservation of native breeds is also an important component of poultry biodiversity. The Food and Agriculture Organization of the United Nations (FAO) stated that 55% of all local poultry breeds are found in Europe and the Caucasus regions [16]. In Italy 22 breeds have been included in the Indigenous Poultry Register and most of them are included in the FAO Domestic Animal Diversity Information System (DAD-IS) database [17].

In European developed countries, like Italy, both, at national and EU levels, the development of sustainable farming systems and the protection of biodiversity (animal and vegetal) are encouraged, especially in the more rural areas and the collaboration between associations, farmers, and scientific partners such as universities is incentivized. For this reason, the Italian Ministry of Policies Agricultural, Food and Forestry funded the project PRIN "*USE OF LOCAL CHICKEN BREEDS IN ALTERNATIVE PRODUCTION CHAIN: WELFARE, QUALITY AND SUSTAINABILITY*" with the aim to promote the use of local chicken breeds in alternative production chains through the development of crossbreeds to increase the production efficiency. This fact represents an opportunity to mobilize some resources on the breeding of local breeds and products that generate work and quality products obtained from animals that are naturally present in the territory [10]. In particular, in Italy there are some associations such as the Consortium for the Bionda Piemontese breed and Veneto Agriculture [11], partners of the above-mentioned project, that have been working for years for poultry Italian breeds conservation and to provide assistance and birds to new and old rural farmers. The Bionda Piemontese (BP), is a native breed of the Piedmont region (north-west, Italy) is characterized by a blond plumage and a black tail. Currently they are bred mainly for meat production and are slaughtered at around 24 weeks of age, although they are considered dual-purpose breeds. In 2013, the population size was 16,000 birds. The annual laying production is concentrated in the spring-summer period and is around 180-200 units [12]. The breeders of BP and RM are included in the Consortium for the conservation of the breed and in the biodiversity conservation project of Italian poultry breeds and sponsored by the Ministry of Policies Agricultural, Food and Forestry. Knowledge of growth performance is therefore considered a requirement and a fundamental contribution to the improvement and conservation of local poultry breeds.

The Robusta Maculata (RM) is a native breed of the Veneto region (north-east, Italy) characterized by a silver-white plumage edged and irregularly spotted with black. It is a dual-purpose breed with a good aptitude for egg production and medium precocity. The Robusta Maculata is a rustic breed with good grazing aptitude and able to adapt to different agricultural environments. It adapts well to both extensive breeding and organic farming. Roosters reach a weight of 3.8-4.4 kg while females weigh an average of 2.8-3.3 kg. It is quite early and lays eggs with a pink to brown colour. Production is around 140-160 pieces per cycle with a weight of 55-60 g. The meats are delicate and abundant. The recommended slaughtering age is 18-22 weeks [13].

The sustainable use of genetic resources in extensive and organic systems is an alternative practice to industrial farming [14]. BP and RM perform well in these alternative systems and retain adaptation to low input farming systems that can positively affect welfare and quality; the products obtained are officially recognized as traditional and usually sold as whole carcasses and/or processed meat products [23, 24]. These properties contribute to the value of this production and support the proposal of a retention situation for this breed.

In the present research, preliminary results of the growth performance and behavioural patterns of BP and RM chickens and their F1, crossed with a higher productivity breed

(Sasso), were evaluated and compared with the Ross308 chickens in two housing systems (industrial and free-range), to identify the breed better adapted for a particular system, offering the greatest benefits in terms of productivity and welfare.

2 Materials and methods

2.1 Birds and housing systems

The present trial was performed in the poultry farm of the Department of Veterinary Sciences of University of Turin (Italy), from March to July 2021.

300 chicks of five different poultry genotypes, Robusta Maculata (RM), Bionda Piemontese (BP), RM x Sasso (RMxS), BP x Sasso (BPxS) and commercial hybrid (Ross 308) were hatched by a local farmer [17]. Chicks were vaccinated against Marek and Newcastle diseases and sexing was done based on visual analysis of cloaca at hatching.

Chicks were allotted for the first 20 days in the brood divided into five pens, one for each genotype. Each pen was 1 m wide and 2 m long and was covered with wood shavings (20 cm deep) as litter equipped with a waterproof floor and walls, environmentally controlled with temperature and relative humidity (RH) ranging from 32 to 20°C and from 70 to 65% RH, respectively.

At 21 days until slaughter, birds were randomly divided into two different rearing systems: industrial (33 kg of meat per m²) and free-range (21 kg of meat per m²). For each genotype and system, three replicates were made (n = 10 cockerels/5 genotypes /2 housing systems/3 replicates).

In the industrial system, the lighting schedule was 16 h light, 8 h darkness for the whole trial. Environmental conditions in the house, temperature and relative humidity, were set according to the Ross guidelines [18]. Whereas for free-range system no lightning schedule was set, and temperature and light were the naturals, and the animals were left free to stay either outside or inside at any time of the day, outdoor access were closed for the night (20.00-06.00) till May and then left open till the end of experimentation.

All the facility, including the outdoor areas, was protected from wild birds and predators with fences. The animals and the environmental parameters were daily checked during the whole experimental period.

Slaughtering was performed in a commercial slaughterhouse at two different ages:

1. Ross industrial birds have been slaughtered at 42 days old according to European Union standards for poultry meat production [19].
2. Free-range Ross, LBs and crossbred birds have been slaughtered at 81 days old, accordingly to European Union recommendation for poultry organic production [20].

Bioethical Committee of the University of Turin (Italy) evaluated ethical aspects and approved the experimental protocol (Prot. ID: 251833).

2.2 Diets

Two different feeds were used a starter and a finisher diet. Starter diet was the same for all birds from 0 to 21 days, whereas the finisher diets were with the recommended energy and protein levels for Ross (industrial group) and with a reduced content of both and by partial replacement of soybean with alternative legume, GMO free and from Italian cultivations, for free-range group (Table 1).

Table 1. Formulation (%), chemical composition (% dry matter) and energetic value (MJ kg⁻¹) of diets.

Housing System	Industrial	Free-range
Diet	Starter	Grower

Ingredients			
Corn	55	57	58
Soybean oil	2	3	2
Soybean meal*	-	-	20
Soybean meal**	25	15	-
Whole Soy	14	21	-
Broad bean	-	-	16
Calcium Carbonate	1.8	1.8	1.8
Monocalcium phosphate	1.3	1.3	1.3
Sodium chloride	0.4	0.4	0.4
Vitamin/Mineral [‡]	0.5	0.5	0.5
Chemical composition			
Dry matter	88.65	88.62	87.74
Crude protein	22.02	19.76	17.67
Ether extract	7.27	9.52	4.63
Crude fibre	2.99	2.97	3.82
Ash	6.53	6.42	6.34
Lysine	1.20	1.07	0.95
Met. + Cist.	0.71	0.66	0.53
Football	1.01	1.00	0.99
Phosphorus	0.70	0.68	0.68
Ca/P	1.44	1.46	1.46
Metabolizable Energy	3089	3252	2921

*: National Soybean meal GMOs free, 44.0% PG. **: Imported Soybean meal GMO, 49.0% PG.: Amounts per kg: Vit. A 11,000 U; Vit. D3 2000 U; Vit. B1 2.5 mg; Vit. B2 4 mg; Vit. B6 1.25 mg; Vit. B12 0.01 mg; α -tocopheryl acetate 30 mg; Biotin 0.06 mg; Vit. K 2.5 mg; Niacin 15 mg; Folic acid 0.30 mg; Panthotenic acid 10 mg; Choline chloride 600 mg; Mn 60 mg; Fe 50 mg; Zn 15 mg; I 0.5 mg; Co 0.5 mg.

2.3 Productive performance

Chickens were individually weighed (LW) every week using an electronic scale (KERN PLE- N v. 2.2) and feed intake (FI) was weekly recorded. Daily weigh gain and feed/gain ratio (FCR) was also calculated. To calculate mortality death birds were also daily recorded and causes of death evaluated by necropsy.

2.4 Behavioural analysis

During the week prior to slaughtering (from 36 till 41d and from 73 to 80 d of age), behavioural observations using a digital video camera (Sony 4K, FDR-AX43) were performed. The videos were analysed afterwards by two trained observers, using the continuous sampling method [21] for three minutes for each replication, in the morning (09.00h) and afternoon (17.00 h), during 2 periods of 1.5 h each.

The behavioural observations (Table 2) were divided into 6 macro-categories: feeding (scratching, feeding from feeders and drinkers, grass/object pecking); locomotor (walking, running, flapping wings while running); social (menacing each other without fighting, fighting, gentle pecking, allo-preening); resting (crouching, standing still); comfort (sand bath, self-preening); stretching (leg stretching, wing stretching).

The behaviour was recorded on a purpose-designed table (based on the major behaviours in the broiler ethogram chosen from preliminary observations), and their respective frequencies were calculated as a percentage of the total observed behaviours. As no significant differences were found between age and period, all data were pooled.

Table 2. Designed table of macro-categories and corresponding behaviours used for behavioural analysis.

MACRO-CATEGORIES	BEHAVIOUR
Feeding	<i>Scratching</i> <i>Feeding</i> <i>Grass/objects pecking</i>
Locomotor	<i>Walking</i> <i>Running</i> <i>Wingflap running</i>
Social	<i>Menacing</i> <i>Fighting</i>
	<i>Gentle Pecking</i> <i>Allo-Preening</i>
Resting	<i>Crouching</i> <i>Standing</i>
Comfort	<i>Sand bath</i> <i>Self-Preening</i>
Stretching	<i>Leg stretching</i> <i>Wing stretching</i>

2.5 Statistical analysis

A linear model [22] was used to evaluate the effect of genotype and housing system. For final live weight the repeated effect of chicks was included as random in the model.

Gompertz coefficients have been evaluated for the different genetic groups with the proc NL using the non-linear following equation:

$$LW_{wk} = b1 * \exp \{-\exp [-b3 * (\text{time in wk} - b2)]\}, \quad (1)$$

LW_t was the live weight of any chicken at a given wk, $b1$ = adult weight (asymptote), $b2$ = the slope at flex point and $b3$ = the point of flex.

Goodness of fit of the model to the data was determined on each breed and housing system separately using adjusted coefficient of determination (r^2).

Difference between groups were assessed by ANOVA test with a Bonferroni multiple t-test. Differences with at least a $P < 0.05$ value were considered statistically significant. Nonparametric tests were performed on the behavioural categories and mortality rate and significance was evaluated by χ^2 value and set at $P < 0.05$.

3 Results and discussion

3.1 Growth performance

The data relating to the productive performance are shown in Table 3. All parameters (LW, FI, FCR, mortality) showed significance ($P < 0.05$) for genotype and strong significance ($P < 0.005$) for housing system and interaction of housing system x genotype effects. As expected, the final LW (at 42d for industrial Ross and 81d for other birds), the FI and the FCR differed between genotypes with higher values for Ross 308 compared to LB and their crossbred, in both industrial and free-range systems. Mortality rate showed interesting results. Ross mortality was significantly ($P < 0.005$) higher in both rearing systems with higher percentage in the free-range system compared to the industrial. Ross growth performance comparison between the two rearing systems shows how this HPS performs less in a free-range system, while on the other hand, all LB and F1 crossed birds considered performed similarly in the two different rearing systems. These results can be compared to previous research [29, 30] and explained by the strong genetic selection for meat yield. In fact, in industrial system Ross 308, provide increasingly better growth performances and unparalleled yields, but the obvious consequence is that these animals are more susceptible to environmental variations, reducing their adaptability to uncontrolled environments and making them inappropriate for any type of farming other than the industrial intensive one. LBs, on the other hand, showed lower to none mortality rate in the free-range system, thus implying a better resilience of these animals and a more appropriate fit to this rearing system [25], although the duration of the fattening period was longer, in both systems. Causes of Ross mortality were related to fast growth and were mainly 65% Sudden Death Syndrome (SDS) and 35% ascites in industrial system, whereas for free-range mainly ascites. This lower incidence of SDS in the free-range system was probably a consequence of the lowering of the growing rhythm due to the housing system (diet + uncontrolled environmental condition + lower density + higher locomotor activity) [32, 33].

Table 3. Productive performance of each genotype in the two rearing systems

Housing System	Genotype	LW (g)	FI (g/d)	FCR	Mortality (%)
Industrial	BP	1587	67.88	4.95	1.2
	BPxS	1982	81.58	4.88	<u>0.9</u>
	RM	1626	70.38	5.03	<u>1.4</u>
	RMxS	2035	82.38	4.57	<u>1.7</u>
	Ross***	2617	151.78	2.77	<u>2.6</u>
Free-range	BP	1747	69.11	5.27	<u>0.0</u>
	BPxS	2056	87.81	5.04	<u>0.0</u>
	RM	1691	67.61	5.54	<u>0.5</u>
	RMxS	2035	76.61	4.93	<u>0.0</u>
	Ross	4726	139.10	3.69	3.9

Significance of effect

Housing	**	**	**	**
Genotype	*	*	*	*

* = P < 0.05. ** = P < 0.005. *** = LW, FI, FCR and Mortality at 42d of age. H = housing system. G = genotype.

Another interesting intake of these results is that for the F1 crossbred (BPxS, RMxS) showed adequate performance in both environments, conjugating the strength and resistance of LB with higher yields [34, 35]. The FI was lower in free-range housing system of LB and their crossbred, probably thanks to the grass ingestion (as confirmed by behavioural analysis; data not shown), among other things, positively conditioning the other production parameters such as LW, FCR and mortality, too. These results are confirmed also by previous works [30] in different genotypes (mainly HPS vs LB) reared in organic system, where grass ingestion improved LB health and welfare and products (meat and egg) quality.

The crossing of pure breeds with HPS [31] had a positive impact in LW of LB genotypes, in both rearing systems, this result can be deeply analysed observing the LW Gompertz curves (fig. 2, 3). In fact, as previous studies confirm [32], BP has a faster growing rate in the first part of its life cycle (4-7 weeks), while RM in the second part of its life cycle (8-13 weeks). In the Gompertz model, parameter b3, which was related to the shape of the growth curve, showed positive correlation with BW and in RM free-range birds showed the highest value (11.75, r² = 0.99). Crossing LB with HPS bird line, improved RM growth in the first phase while in the second sustained the BP growth allowing the curves of BPxS with RMxS to be comparable since week 1 in both systems (b3 = 9.61 and 10 for BPxS and RMxs, respectively; r² = 0.99 and 1 for BPxS and RMxs, respectively). The relative growth rate b2, related to the slope of the curve, was the highest in industrial Ross (0.27, r² = 0.98). Accordingly, to slaughter age (42d), the higher b2 value corresponded to a shorter time to reach maturity, namely, a shorter age at inflection point was related to a lower weight attained at that time and at the higher age.

Figure 1. Gompertz distribution of LW from 0 to 13 weeks of industrial system.

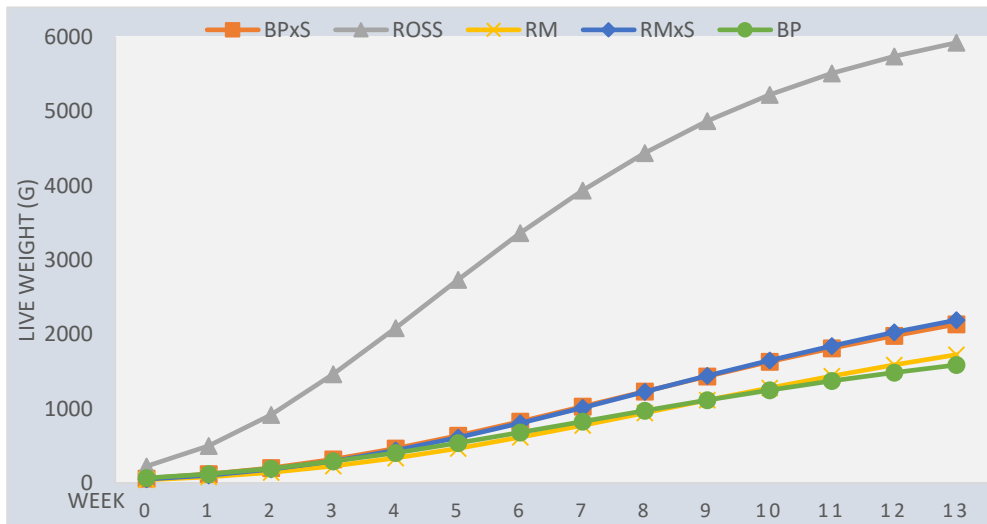
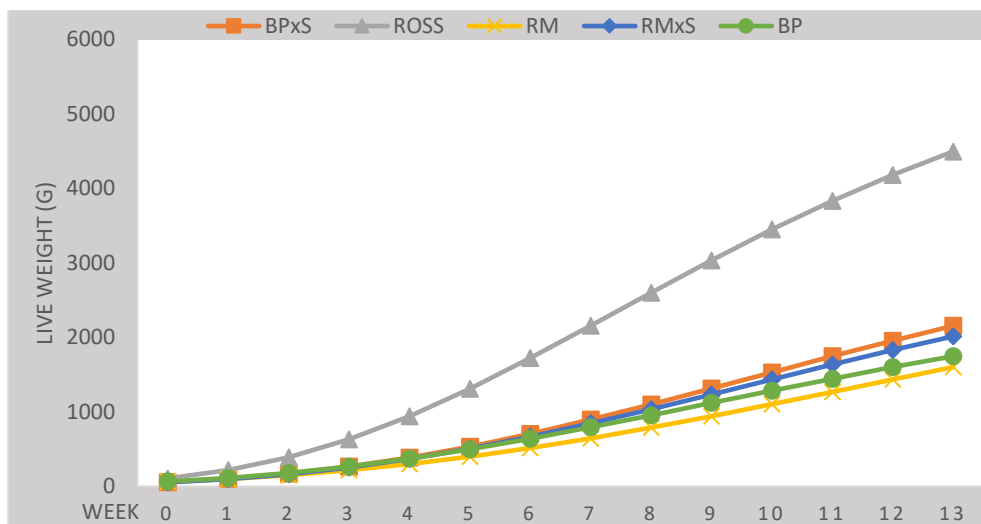


Figure 2. Gompertz distribution of LW from 0 to 13 weeks in free-range system.



3.2 Behavioural analysis

Analysis of animal behaviours in farming is important from a multifactorial point of view; results obtained from more traditional observed point (i.e. performance) in poultry farming, can be put in correlation and explained observing the behaviour that animals show [33].

The results obtained are present in table 4; macro-categories like feeding, locomotor, resting and comfort showed strong significance ($P < 0.005$) for housing system and genotype, the interaction between housing and genotype was significant ($P < 0.05$) for feeding and rest and showed a strong significance ($P < 0.005$) only for locomotor activities.

Table 4. Behavioural macro-categories of birds in the two rearing systems

Housing System	Genotype	Feeding	Locomotor	Social	Resting	Comfort	Stretching
Industrial	Bp	22.56	23.48	4.03	41.65	4.39	4.03
	Rm	17.59	30.80	4.43	38.65	4.28	4.24
	Bp X S	21.63	25.44	3.71	41.90	3.08	4.23
	Rm X S	17.40	20.91	2.97	50.18	5.20	3.35
	Ross ^ψ	14.99	12.32	0.00	59.21	2.92	11.28
Free-Range	Bp	34.09	41.70	5.98	13.45	3.50	1.52
	Rm	32.20	41.85	3.85	17.37	3.07	1.65
	Bp X S	34.07	41.05	5.44	16.94	1.35	1.14
	Rm X S	40.22	38.75	5.73	11.45	3.23	0.75
	Ross	21.25	13.39	0.18	53.82	5.30	7.45
P Value	Housing	**	**	-	**	**	*
	Genotype	**	**	-	**	**	*
	H X G	*	**	-	*	-	-

* = $P < 0.05$. ** = $P < 0.005$. ^ψ = Behaviour recording from 36 until 41d.

To deeply understand differences found in birds feeding activities, we must analyse the behavioural patterns that constitute this macro-category. In fact, feeding was constituted by scratching, feeding from feeders and drinkers, and grass/object pecking. In free-range birds, feeding was mainly constituted by grass pecking in all genotypes, while in industrial, this

behaviour was not allowed, and it was substituted by pecking objects. Regarding feeding from feeders, the industrial birds performed the greater percentage (data not shown). Respect genotype Ross showed in both systems the highest percentage of feeding from feeders according to due to genetic selection [34].

As expected, in both rearing systems, Ross showed the lowest locomotor activities; particularly interesting is that in both housing systems there was no significant difference, these animals even if given the opportunity of an outside area where they could move freely, spent, like in the industrial housing system, a lot of their daily time resting and feeding at feeders. On the contrary free-range LBs and their crossbred took advantage of the outdoor area, showing more locomotor and less resting feeding at feeders activities compared to industrial farmed animals, these results are confirming previous studies [30] showing how strong genetic selections have impacted the life of this animals.

Since active behaviours (i.e. running and walking) represent an energy cost for the animal, it is plausible that the strong genetic selection carried out to improve productive performance modifies the behaviour of these animals, forcing them to direct as much energy as possible to growth, by limiting some behaviours wasteful in terms of energy [41]. This confirms what has been observed, in both housing systems, regarding Ross, which spent most of their energy on muscle growth, while in LBs a greater percentage of available resources have been used for movement, food search and performing behaviour typical of the chicken ethogram [42]. Consequently, it could be possible that genetic selection for productive traits (i.e. muscle growth, breast yield) indirectly produce animals with a reduced kinetic attitude [43].

Comfort behaviours were mainly constituted by self-preening and sand bath (data not shown) and were mostly performed in industrial system by LBs and their crossbred, while in free range housing system by Ross birds. We could hypothesize that more active birds like LBs and their crossbred, when reared in confined environment, increase the time spent in performing allowed behaviours, this hypothesis was confirmed by the findings of the same genotypes in free-range that lowered the frequencies of this behavior, being free to perform their natural ethogram.

Ross when compared to LBs and crossbred performed stretching more. Leg and wing stretching intended as extending these parts from the body could be performed in order to relieve pain or discomfort due to the posture [44] in meat type birds. On the contrary, other studies have also reported that a lack of stretching could be a sign of compromised bird health [45]. LBs and crossbred lower frequencies of stretching could be explained by the fact that these last were engaged performing other behaviors of their ethogram. Previous studies conducted in laying hens have showed that stretching could be mainly linked to the productive factors of farming, such as the type of soil confirming that HPS are less tolerant if environmental conditions are not ideal [46, 47].

4 Conclusion

Our results clearly demonstrate that Ross birds increase their mortality in free-range system, whereas in the same system, LB and their crossbred increased their productive performance with the lowest mortality and then better welfare. These findings, clearly show how HPS such as Ross 308 can give unparalleled meat yields in industrial system, with high quality feed, controlled environment and short life cycle. If these conditions are not guaranteed, such as in free-range, Ross genotype birds did not take advantage of space and pasture allowance and did not modify their behavioural patterns as opposed to LB and their crossbred. We can then state that, LB and their crossbred can better adapt to alternative farming systems, showing resilience of local poultry production to environmental changes. Moreover, the crossbreeding of LB with a more productive breed could have a great effect in improving

productive performance without impairing animal behaviour and welfare, increasing both the economic income for local farmers and the preservation of poultry local breed biodiversity. This is useful knowledge both for less developed and developed countries where it is important to develop low input farming systems to sustain local communities and economies, and to meet consumers' demands of animal products with higher welfare and ethical value being. We can then conclude that less productive chicken breeds can represent a feasible alternative in the appropriate rearing system. Further experimental trials regarding this argument could be performed as very little previous bibliography is present on the argument, it could be particularly interesting to analyse in more details the increase in performance in relation to strength and resilience of population of LB crossed with higher productive strains.

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