Influence of different housing systems on the performance of hens of four laying strains

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Four laying strains were evaluated with regard to henday egg production, egg mass, feed conversion, mortality, Haugh units, shell thickness and percentage soiled, cracked and broken eggs produced under a battery, floor house and free-range system. This was done to determine whether significant differences do exist in performance between the different housing systems and to identify any stain × housing system interactions that may be present. Strain accounted for most variation in all the tested traits. Overall the battery system seems to be more advantageous than the other systems, yielding a significantly higher henday egg production than the free-range system, a significantly higher egg mass than in the floor house system, a significantly better feed conversion than both the floor house and free-range systems, significantly less mortalities and less soiled, cracked and broken eggs than both the other systems. Strain × housing system interactions were observed with regard to feed conversion and mortality.

Vier lêrasse is geëvalueer ten opsigte van hendageierproduksie, eiermassa, voeromset, mortaliteit, Haugh-eenhede, dopdikte en persentasie vuil, gekraakte en gebreekte eiers verkry vanaf 'n battery-, vloerhuis- en veldkampstelsel. Dit is gedoen om vas te stel of daar betekenisvolle verskille bestaan in prestasie tussen verskillende behuisingstelsels en om enige ras × behuisingstelselinteraksies wat teenwoordig mag wees, te identifiseer. Die meeste variasie in die gemete eienskappe word deur ras verklaar. In die geheel blyk die batterystelsel voordeliger te wees as die ander twee stelsels. 'n Betekenisvolle hoër hendageierproduksie word in die batterystelsel as in die veldkampbehuisingstelsel verkry, 'n hoër eiermassa as in die vloerhuisstelsel, 'n beter voeromset as in albei die ander behuisingstelsels, laer mortaliteit en 'n laer persentasie vuil, gekraakte en gebreekte eiers as in die vloerhuis- en veldkampbehuisingstelsels. Ras × omgewingbehuisingstelselinteraksies is waargeneem ten opsigte van voeromset en mortaliteit.

Keywords: Feed conversion, Haugh units, henday egg production, housing system, strain.

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Introduction

Welfare criteria for animal husbandry systems are incorporated in 'Five Freedoms', namely, freedom from hunger and thirst, freedom of movement, freedom from pain, fear and distress, freedom from injury and diseases, and freedom to exercise most normal patterns of behaviour. Housing systems for poultry have already been widely discussed (Phelps, 1991; Van Horne, 1991; Dun, 1992; Sherwin & Nichol, 1992; Von Petersen, 1992). It seems that every system has advantages and disadvantages concerning the freedoms. The battery system (cages) has welfare advantages, such as a clean, low disease-risk environment, in which hens are separated from their droppings, and small group sizes, which can minimize the risk of cannibalism (Dun, 1992). On the other hand, freedom of movement and freedom to exercise normal patterns of behaviour are inhibited by this husbandry system. Free-range chickens and their eggs are more likely to be infected by salmonella than caged birds and their eggs. These chickens are susceptible to the same metabolic diseases affecting intensively kept birds, but the environment can influence their severity and also make the birds susceptible to syndromes rarely found in caged layers. Free-range chickens are subjected to harsh environmental conditions and predators, but they do have the freedom of movement and freedom to exercise most normal patterns of behaviour. Layers kept on litter are subjected to the build up of humidity and ammonia concentrations. The birds' respiratory systems are weakened in these conditions and they are more susceptible to bacteria and virus infections (Phelps, 1991). Furthermore, cannibalism can be a major and unpredictable problem in deep-litter systems (Dun, 1992). These chickens do, however, have more freedom of movement and natural behaviour than caged chickens.

According to Cahaner (1990), Sorenson (1989) studied strain × housing system interactions for meat type chicken reared in cages vs. rearing on the floor. Genetic effects and the effects of single vs. nine-bird colony cages upon the percentage production of soft-shell, shell-less and hard-shell eggs were investigated by Patterson & Muir (1986) in a random-bred population of White Leghorns. A significant sire × cage environment interaction was found for percentage shell-less eggs. This interaction was, however, due to scale effects and not to a re-ranking of sire means. Abrahamsson & Tauson (1993) studied laying performance, health and behaviour in two strains of Leghorn hens in three-tier battery cages with a perch fitted across the cage 17 or 24 cm from the back, or housed in control cages without a perch. They found significant interactions between strain and cage design regarding laying percentage, egg weight, cracked eggs, live weight, foot and perch hygiene, keel bone condition and toe pad hyperkeratosis.The aim of this study was to investigate the performance of hens of four laying strains in a battery, floor house and free-range housing system, in order to determine whether significant differences do exist in performance between the different systems and to identify any strain × housing system interactions that may be present.

Materials and methods

Hens of four laying strains were evaluated with regard to henday egg production, egg mass, feed conversion, mortality, Haugh units (internal egg quality), shell thickness and percentage soiled, cracked and broken eggs produced under three housing systems. Henday egg production, rather than hen housed egg production, was used as indicator of the number of eggs produced, since hen mortalities are incorporated by this parameter. The housing systems used included a battery system [stocking density 0.1 m^2/hen (one hen per cage)], a floor house system (stocking density 0.2 m^2/hen) and a free-range system (stocking density 3.9 m^2/hen). The strains which were evaluated, were New Hampshire (NH), Strain A, Strain B and Strain C.

The New Hampshire hens were obtained from a New Hampshire Control Flock which was founded in 1977 at the Glen Agricultural College. The base population consisted of 50 cocks and 250 hens, randomly chosen from a flock of the University of Pretoria. Full- and half-sib matings were avoided. From each cock one son and from each hen one daughter were randomly kept as parents for the next generation. Mating combinations were chosen carefully so that inbreeding was kept to a minimum. This flock has exhibited no genetic change since 1977 (J.J. Joubert, 1993, unpub. data) and could therefore be used as a control in this study. The other strains were obtained from the three most important producers of commercial laying birds in South Africa.

A four (strain) × three (housing system) factorial design was used with 42 hens in every treatment combination. Four

Table 1 Analysis of variance for henday egg production, egg mass, feed conversion, Haugh units and shell thickness

Trait	Source	*df*	SS	F	*P*
Henday egg production	Strain	3	24048.29	47.75	0.001
	Housing system	2	1587.97	4.73	0.015
	Strain × housing system	6	2107.30	2.09	0.078
	Residual	36	6043.44	2.96	
	Total	431	55537.04		
Egg mass	Strain	3	8675.52	780.72	0.001
	Housing system	2	77.29	10.43	0.001
	Strain × housing system	6	34.83	1.57	0.185
	Residual	36	133.35	0.24	
	Total	430	14750.04		
Feed conversion	Strain	3	80.1454	114.62	0.001
	Housing system	2	4.7859	10.27	0.001
	Strain × housing system	6	3.9155	2.80	0.024
	Residual	36	8.391	0.62	
	Total	431	242.5149		
Haugh units	Strain	3	474.08	5.73	0.003
	Housing system	2	55.06	1.00	0.378
	Strain × housing system	6	9.31	0.06	0.999
	Residual	36	992.00	0.43	
	Total	95	4628.92		
Shell thickness	Strain	3	71.87	11.06	0.001
	Housing system	2	20.08	4.63	0.016
	Strain × housing system	6	29.00	2.23	0.062
	Residual	36	78.00	0.08	
	Total	95	1522.96		

repetitions of every treatment were made.

The chicks hatched in September 1992. Until four weeks of age they were reared in chicken batteries and then randomly allocated to the different treatments. The chickens were not debeaked and they were reared under natural daylight. Natural daylight was also used during the evaluation period in all housing systems. From day-old until 8 weeks of age chick starter mash was fed, from 8 weeks up to 18 weeks of age growing mash and from 18 weeks onwards laying mash. The evaluation period started when the hens were 24 weeks of age. Nine periods of 28 days each were completed. The hens were thus evaluated over a total period of 252 days (from 24 weeks to 60 weeks of age).

For the determination of Haugh units and shell thickness, three eggs of every repetition of every treatment were randomly chosen during Periods 5 and 7. Egg shells were allowed to dry for at least one week before egg shell thickness was determined. The internal quality of the eggs, measured in Haugh units, was calculated as follows:

$$\text{Haugh units} = 100 \log (H - 1.7\ W^{0.37} + 7.6),$$

where

H = albumen height

W = egg mass (Random Sample Egg Production Test, 1991/92).

For the analyses the data were pooled over all periods. The effect of strain, housing system and the interaction between them on henday egg production, egg mass, feed conversion, Haugh units and shell thickness was determined by analyses of variance for a 4 (strain) × 3 (housing system) factorial design using the Genstat 5 statistical program. Tests of significance ($P \leq 0.05$) were completed using the Bonferroni Multiple Comparison Test.

Mortality was determined as the number of hens that died out of 42. These data were analysed assuming the Binomial distribution of errors and using the generalized linear model (GLM) approach of the Genstat 5 statistical program.

Results

From the analysis of variance (Table 1) it could be seen that the henday egg production, egg mass and shell thickness were significantly influenced by strain and housing system. Feed conversion was, however, also significantly influenced by the interaction between strain and housing system, while strain was the only factor having a significant effect on Haugh units.

Henday egg production

From the analyses of variance (Table 1) it can be determined that strain alone accounted for 43% of the variation [SS (strain)/SS (total)] in henday egg production, while housing system only accounted for 3% of the variation. From Table 2 it is clear that NH hens had a significantly ($P \leq 0.05$) lower henday egg production than the hens of the other strains and that a significantly ($P \leq 0.05$) lower henday egg production was obtained in the free-range housing system.

Egg mass

Again strain alone accounted for 59% [SS (strain)/SS (total)] of the variation in egg mass, while housing system accounted for only 0.5% of the variation (Table 1). Table 3 indicates that Strains A and C did not differ significantly ($P \geq 0.05$), but they both produced eggs with significantly ($P \leq 0.05$) higher egg masses than NH and Strain B hens. Furthermore, eggs produced in the battery and free-range systems were significantly ($P \leq 0.05$) heavier than eggs produced in the floor house system.

Feed conversion

Feed conversion is defined as kg feed consumed per kg eggs produced. With regard to feed conversion, strain accounted for 33% of the variation, housing system for 2% and the inter-

Table 2 Least-squares means and standard errors (SEs) for henday egg production by strain and housing system (CV = 10.1%)

Strain means and (SEs) :	NH	A	B	C
	61.73^a (1.247)	77.11^b (1.247)	80.96^b (1.247)	77.85^b (1.247)
Housing system means and (SEs) :	**Batteries**	**Floor house**	**Free-range**	
	75.62^a (1.08)	75.91^a (1.08)	71.71^b (1.08)	

$^{a-b}$ Least-squares means in the same row with different superscripts differ significantly ($P \leq 0.05$)

Table 3 Least-squares means and standard errors (SEs) for egg mass (g) by strain and housing system (CV = 6.5%)

Strain means and (SEs):	NH	A	B	C
	53.27^a (0.185)	64.40^c (0.185)	60.19^b (0.185)	64.07^c (0.185)
Housing system means and (SEs) :	**Batteries**	**Floor house**	**Free-range**	
	60.98^b (0.16)	59.94^a (0.16)	60.52^b (0.16)	

$^{a-c}$ Least-squares means in the same row with different superscripts differ significantly ($P \leq 0.05$)

Table 4 Least-squares means and standard errors (SEs) for feed conversion by strain, housing system and the interaction between strain and housing system (SE of interaction means = 0.0805) (CV = 24.6%)

Strain	Batteries	Floor house	Free-range	Strain means and SEs
NH	3.049^{b}	3.486^{c}	3.189^{bc}	3.241^{b} (0.0465)
A	2.111^{a}	2.134^{a}	2.397^{a}	2.214^{a} (0.0465)
B	2.149^{a}	2.361^{a}	2.423^{a}	2.311^{a} (0.0465)
C	2.109^{a}	2.161^{a}	2.407^{a}	2.226^{a} (0.0465)
Housing system means and SEs	2.355^{a} (0.0402)	2.535^{b} (0.0402)	2.604^{b} (0.0402)	

$^{a-c}$ Least-squares means with common superscripts do not differ significantly ($P \geq 0.05$)

action between strain and housing system for 1.6% of the variation. From Table 4 it is clear that NH hens used significantly ($P \leq 0.05$) more food than hens of the other strains to produce one kilogram of eggs. A significantly ($P \leq 0.05$) better feed conversion was obtained in the battery system than in the other housing systems. The result is not surprising, since feed wastages and activities can be kept a minimum in a battery housing system. No significant differences ($P \geq 0.05$) existed between the commercial strains in the different housing systems. NH hens, however, had a higher feed conversion than the hens of all the other breeds and feed conversion of these hens was significantly ($P \leq 0.05$) higher in the floor house system than in the battery system.

Mortality

From Table 5 it can be seen that there is overall strong evidence ($P \leq 0.01$) that the three housing systems differed with respect to mortality. Relative to the battery system, the odds ratios for the house and free-range systems were $e^{1.230} = 3.4$ and $e^{1.266} = 3.5$. Therefore, hens in floor house and free-range housing systems were nearly three and a half times more likely to die than hens in batteries. The differences between housing systems alone accounted for 54% of the variation in mortality. Generally, there is no evidence of differences between strains, but evidence of ($P \leq 0.05$) strain by housing system interactions in mortality do exist.

Table 5 Estimates of regression coefficients, standard errors (SEs), *t*-values and odds ratios for the different housing systems, strains and interactions between strain and housing system for mortality

	Estimate	SE	*t*	Odds ratios
Constant	–2.565	0.299	–8.56	
Floor house	1.230	0.355	3.47	3.42
Free-range	1.266	0.354	3.58	3.55
Strain A	–0.431	0.470	–0.92	0.65
Strain B	–0.195	0.443	–0.44	0.82
Strain C	0.167	0.409	0.41	1.18
Strain A × floor house	1.527	0.530	2.88	4.60
Strain A × free-range	1.270	0.530	2.39	3.56
Strain B × floor house	1.363	0.506	2.69	3.91
Strain B × free-range	0.047	0.520	0.09	1.05
Strain C × floor house	0.338	0.481	0.70	1.40
Strain C × free-range	0.002	0.485	0.00	1.00

The four strains did not differ very much with regard to mortality in the battery system (Table 6), but in the floor house system mortality ranged from 21% for the NH hens to 46% for the Strain B hens and in the free-range system from 19% for the Strain B hens to 39% for the Strain A hens. Because the floor house and free-range systems were exposed to petty theft, mortalities in these systems were extremely high.

Haugh units

With regard to Haugh units, strain accounted for only 10% of the variation (Table 1). From Table 7 it is clear that Haugh units of eggs produced by the commercial strains did not differ significantly ($P \geq 0.05$), while the Haugh units of eggs produced by NH hens were significantly ($P \leq 0.05$) lower than that of Strain B hens. The finding that housing system had no significant influence on the Haugh units of the eggs produced in the different systems was in contradiction with the results of North (1984), who found that internal egg quality dropped more quickly in the case of caged layers than on a litter floor. Pavlovski *et al.* (1981) also found that eggs from extensive production had a higher albumen and more Haugh units than eggs from intensive production.

Shell thickness

Five per cent of the variation in shell thickness could be accounted for by strain differences, while housing system only accounted for 1% of the variation (Table 1). NH hens produced eggs with significantly ($P \leq 0.05$) thinner egg shells than that of the commercial strains. No significant differences ($P \geq 0.05$), however, existed between the commercial strains for egg shell thickness. Since the Bonferroni Multiple Comparison Test is a less sensitive test than the *F*-test, no differences were found between housing systems with regard to shell thickness. Shell thickness of eggs produced in the free-range system was, however, 1 μm and 0.94 μm thicker than that of eggs produced in the battery and floor house systems, respectively (Table 8). Pavlovski *et al.* (1981) found that eggs from extensive production had harder egg shells than eggs

Table 6 Predictions (P) and standard errors of predictions [SE (P)] of the percentage mortality expected in every housing system, for each strain, as well as for interactions between strain and housing system

	Batteries		Floor house		Free-range		Ps and (SEs) of mortalities for each strain
	P	SE (P)	P	SE (P)	P	SE (P)	
NH	0.0714	0.0199	0.2083	0.0313	0.2143	0.0316	0.1647 (0.0162)
A	0.0476	0.0164	0.4405	0.0383	0.3869	0.0376	0.2917 (0.0187)
B	0.0595	0.0183	0.4583	0.0384	0.1905	0.0303	0.2361 (0.0174)
C	0.0833	0.0213	0.3036	0.0354	0.2440	0.0331	0.2103 (0.0177)
Ps and (SEs) of mortalities in each system	0.06548 (0.00953)		0.35268 (0.018)		0.25893 (0.01664)		

from intensive production, while North (1984) found that egg shell quality deteriorates more rapidly when layers are kept in cages than on a litter floor.

Percentage soiled, cracked and broken eggs collected

As expected the highest percentage of soiled eggs was obtained in the free-range system and the lowest percentage in the battery system for all the strains (Figure 1). This result is in accordance with that of Pavlovski *et al.* (1981), who found that there was significantly more dirt on eggs from extensive production (8.89%) than on eggs from intensive production (1%). Dun (1992) also found that eggs from caged layers are laid into a cleaner environment and the risk of egg shells and their content becoming contaminated is much lower than in alternative systems.

Less cracked eggs were also collected in the battery system than in the other systems, while a clear tendency could not be defined between the floor house and free-range systems with regard to percentage cracked eggs obtained (Figure 2).

Except for eggs produced by Strain C, a lower percentage eggs of the other strains were broken in the battery system than in the other housing systems. The lowest percentage of broken eggs of Strain C hens was collected in the free-range system, with nearly no difference between the eggs collected in the battery and floor house systems (Figure 3).

Discussion

Although strain accounted for most variation in all the tested traits, except mortality, the commercial strains did not perform significantly different from each other for most of these traits. The NH hens, being a strain unselected for any egg production characteristics, had a significantly ($P \leq 0.05$) lower henday egg production, egg mass, feed conversion and shell thickness than the commercial strains. Most of the variation was therefore caused by the difference in performance between the control strain and the commercial strains.

Overall the battery system seems to be more advantageous than the other systems, yielding a significantly higher henday

Table 7 Least-squares means and standard errors (SEs) for Haugh units by strain and housing system (CV = 9.4%)

Strain means and (SEs):	NH	A	B	C
	83.04^{a} (1.072)	85.82^{ab} (1.072)	89.27^{b} (1.072)	64.44^{ab} (1.072)
Housing system means and (SEs):	Batteries	Floor house	Free-range	
	86.52^{a} (0.928)	86.33^{a} (0.928)	84.83^{a} (0.928)	

$^{a-b}$ Least-squares means in the same row with different superscripts differ significantly ($P \leq 0.05$)

Table 8 Least squares means and standard errors (SEs) for shell thickness (µm) by strain and housing system (CV = 16.1%)

Strain means and (SEs):	NH	A	B	C
	31.12^{a} (0.300)	33.17^{b} (0.300)	32.88^{b} (0.300)	33.25^{b} (0.300)
Housing system means and (SEs):	Batteries	Floor house	Free-range	
	32.25^{a} (0.260)	32.31^{a} (0.260)	33.25^{a} (0.260)	

$^{a-b}$ Least-square means in the same row with different superscripts differ significantly ($P \leq 0.05$)

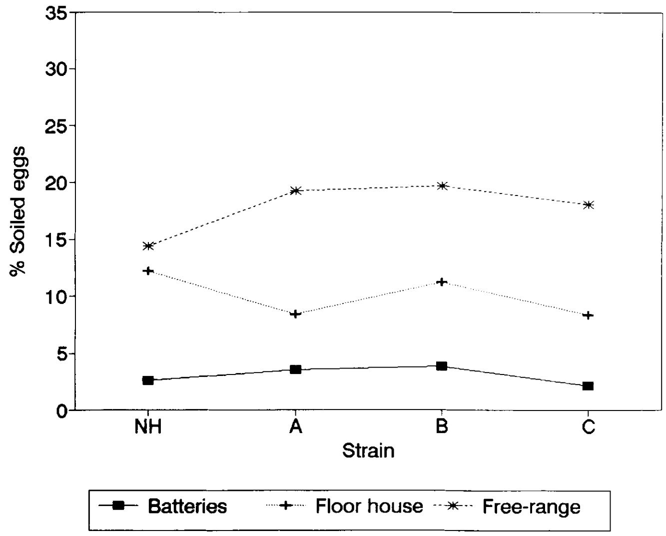

Figure 1 Mean percentage soiled eggs collected in every housing system for every strain

egg production than the free-range system, a significantly higher egg mass than in the floor house system, a significantly better feed conversion than both the floor house and free-range systems, significantly less mortalities and less soiled, cracked and broken eggs than both the other systems. In this study the free-range system was only better than the other two systems with regard to shell thickness. The higher egg masses obtained in the battery system than in the floor house system were not necessarily beneficial. According to Maijala (1984) an optimum egg mass is more beneficial to the market than a maximum egg mass. Too high an egg mass can therefore be undesirable.

Strain × housing system interactions were observed with regard to feed conversion and mortality. From the latter interaction it can be concluded that hens of different strains are not similarly adapted to different housing systems. Most deaths in the battery system were caused by Mareks disease, while cannibalism and theft caused most deaths in the floor house system. The occurence of cannibalism is a clear indication of the

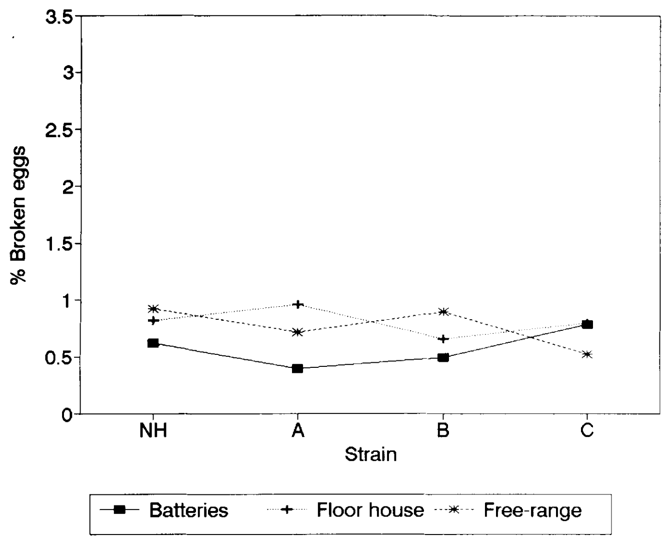

Figure 2 Mean percentage cracked eggs collected in every housing system for every strain

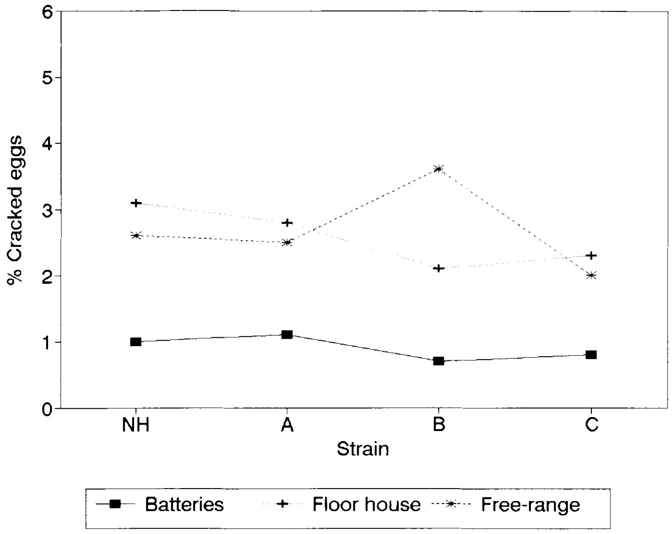

Figure 3 Mean percentage broken eggs collected in every housing system for every strain

stress under which hens live in a floor house system. In the free-range system, cannibalism, predators and theft were the main causes of mortality. Since no significant differences occurred between the commercial strains for most tested traits, the interaction between strain and housing system for mortality enables a producer to use the best adapted strain for his housing system, being Strain A for the battery system, Strain C for the floor house system and Strain B for the free-range system.

Conclusion

Since feed costs compromise 60–70% of total production costs, using a battery system, where food wastages are kept to a minimum, is more economical than the other two housing systems. Furthermore, mortality is significantly lower in a battery system; therefore the laying stock is being preserved, as well as the production obtained from them. Other factors for consideration are the labour involved in the collection of eggs in the floor house and free-range housing systems and the higher percentage soiled, cracked and broken eggs obtained in these two systems compared to the battery system.

Considering all these factors it is clear that the battery system has more advanges for an egg production unit than the floor house or the free-range systems. However, cage design improvements, as discussed by Dun (1992), should be applied if the welfare of the hens is to be improved.

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