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EVALUATION OF BROILER CHICKENS REARING PARAMETERS IN RELATION TO INTENSITY OF INFECTION WITH *EIMERIA* PROTOZOA

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ABSTRACT

The study was aimed to assess the rearing parameters in Ross 308 broiler chickens depending on the intensity of infection with *Eimeria* protozoa. Two flocks were included in the analysis. One was found to be free from coccidiosis (healthy flock HF) and the other was classified as infected flock (IF). The collected data included the age of the chickens, losses (including falls and culls), body weight, weight gains, and daily feed intake. Additionally, the mean feed intake per kg body weight was estimated and the European Production Efficiency Factor (EPEF) was calculated. The study demonstrated that the presence of *Eimeria* parasites in the rearing environment of broiler chickens had an impact on the rearing performance by increasing the demand for feed and the percentage of falls and culls during the rearing period, in comparison with chickens from the coccidiosis-free flock. Although they consumed higher amounts of feed, the coccidia-infected chickens were characterized by substantially lower weight gain values. The EPEF value on rearing day 42 in the *Eimeria*-infected broiler flock was by 103.66 lower than that calculated in the healthy flock.

Key words: broiler chickens, coccidia, feed intake, EPEF, rearing performance

INTRODUCTION

Among the various determinants of the rearing performance and broiler chicken welfare, an important role is played by microbiological contamination in the rearing environment of these birds [Burbarelli et al. 2015, Jiang et al. 2018a]. Birds and their droppings, fodder, and bedding are the main sources of microorganisms [Lonc and Plewa 2010, Wójcik et al. 2010]. The amount and type of microorganisms present in poultry facilities depend on the hygienic conditions, air temperature and humidity, ventilation efficiency, quality and physicochemical properties of the bedding, and flock health status [Witkowska et al. 2010, Bombik et al. 2011, Lewandowska 2012, Stuper-Szablewska et al. 2018]. In the huge number of microorganisms present in poultry facilities, there are saprophytes, pathogens, and microorganisms responsible for enzymatic decomposition of organic matter into ammonia, carbon dioxide, hydrogen sulfide, methane, and many other volatile and aromatic substances [Lonc and Plewa 2010, Bródka et al. 2012, Jiang et al. 2018b]. As shown in many studies [Rathgeber et al. 2009, Świątkiewicz et al. 2009, Lewandowska 2012, Moraes et al. 2015, Blake et al. 2020], intestinal *Eimeria* protozoa, which attack intestinal cells in poultry and cause coccidiosis, are one of the most serious problems in modern poultry production due to their relatively common presence in the environment of poultry rearing and maintenance.

Eimeria tenella, *E. acervulina*, *E. praecox*, *E. necatrix*, *E. maxima*, and *E. brunetti* are coccidia species that commonly infect poultry [Konarkowski 2007, Haug et al. 2008, Pirus 2008, Moraes et al. 2015]. They are characterized by highly varied pathogenicity [Hafez 2008].

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Low-intensity coccidial infection does not produce clinical symptoms in birds [Świątkiewicz et al. 2009]; nevertheless, it causes weaker absorption of nutrients with usually worse feed conversion rates, lower uniformity of the flock, poor growth, weight loss, and possibly falls [Hafez 2008, Świątkiewicz et al. 2009, Lewandowska 2012]. The clinical form of the disease is characterized by enteritis, diarrhea, and increased mortality [Getachew et al. 2008]. Coccidia can also damage the immune system and make poultry more susceptible to other pathogens, e.g. *Clostridium*, *Salmonella*, and *E. coli* [McDougald and Fitz-Coy 2012].

Poultry flocks that are completely free from coccidiosis are very rarely found [Haug et al. 2008]. The course of the disease in infected flocks depends on the *Eimeria* species and their pathogenicity, the number of invasive coccidian oocysts present in the environment and ingested by birds, the age of the birds, and the level of potential resistance to coccidiosis [Mazanowski 2011, Chapman 2014, Gaweł et al. 2015]. The risk of coccidiosis increases with the increase in bird density per unit area, at temperatures exceeding 23°C, and at high humidity of the bedding [Hafez 2008].

Coccidiosis is regarded as one of the most severe health and financial problems contributing to huge global losses in poultry farming. As reported by Michalski [2007], there are direct losses resulting from the falls of sick birds and indirect ones, i.e. poor weight gain, uneven growth, low feed conversion rates, and unfavorable carcass pigmentation. Bera et al. [2010] showed that 68.08% of the annual losses related to coccidiosis in India resulted from reduced body weight gain in broilers and 22.7% were the costs of the increased Feed Conversion Ratio (FCR). EU estimates indicate that the total cost of coccidiosis incurred by producers is approx. 0.05 EUR/broiler, with 70–80% resulting from subclinical coccidiosis [Szeleszczuk et al. 2016]. As shown by Blake et al. [2020], the global cost of coccidiosis in poultry flocks is 10.4 billion GBP, i.e. 0.16 GBP per produced broiler.

The aim of the study was to evaluate the parameters of broiler chicken rearing depending on the intensity of infection with *Eimeria* protozoa.

MATERIAL AND METHODS

The study involved Ross 308 broiler chickens. The birds, originating from the Poultry Hatchery in Mazowieckie Province, were reared on a chicken farm located in the Lublin region. The chickens were maintained in a bedding system in buildings with an area of approx. 2340 m^2. They received fodder produced from components available on the farm (wheat, corn, triticale) and from purchased ingredients (soybean meal, soybean oil, premixes, fodder chalk, rock salt, acidifier, and phosphorus). The farm was under constant veterinary supervision. Microbiological and parasitological tests were carried out systematically to detect diseases in the poultry flocks (e.g. salmonellosis, coccidiosis, reovirosis) and as part of disease prophylaxis.

The diagnostics of coccidiosis on the analyzed farm consisted in determination of the infection intensity. The examinations were performed on the 23rd day of chickens' life. For the analysis, a representative sample of feces weighing approximately 0.5 kg was collected from the entire surface of the henhouse and placed in a plastic bag. The sample was sent to a certified laboratory ("Vet-Lab", Brudzew, Poland) in order to determine the infection level with *Eimeria* oocysts. Depending on the intensity of *Eimeria* infection (II), the farm was assigned a coccidiosis-free status (II up to 9000 oocysts per 1 g of feces) or a coccidia-infected status (II > 9000).

The analysis was performed in two flocks: one was recognized as coccidiosis-free (designated HF) and the other (designated IF), in which the number of oocysts per 1 g of feces exceeded the acceptable level, was classified as an infected flock. The number of birds in both flocks at the beginning and at the end of the 42-day rearing period is shown in Table 1. The data collected in both flocks (based on the "Poultry Breeder's Chart") included: the age of the chickens, losses (including falls and culls for various reasons), body weight, weight gains, and daily feed intake.

Table 1. Number of broiler chickens at the beginning and end of the rearing period in the healthy and coccidia-infected flocks

Tabela 1. Stan liczebny kurcząt brojlerów na początku i na końcu okresu odchowu w stadzie zdrowym i ze stwierdzoną obecnością oocyst kokcydii

	Flock size at the beginning of the rearing period Stan liczebny stada na początku okresu odchowu	Flock size at the end of the rearing period Stan liczebny stada na końcu okresu odchowu
Healthy flock (HF), 12.02–25.03.2018 Stado zdrowe (SZ), 12.02–25.03.2018	32,400	31,764
Infected flock (IF), 13.08–23.09.2018 Stado zarażone (SK), 13.08–23.09.2018	30,100	29,032

The evaluation of chicken losses during the rearing time was carried out in 7-day periods. In each period, the number of fallen and culled chickens was recorded to obtain the total number of losses in the individual rearing periods. Additionally, on the 1st, 2nd, and 3rd day of life of the chickens and in the subsequent 2-day periods, the mean feed intake per kg body weight was estimated based on the weight gains and the amount of ingested feed in both flocks at that time. In both flocks, the value of the European Production Efficiency Factor (EPEF) was calculated in the subsequent periods of chickens' life using the following formula proposed by Kryeziu et al. [2018]:

$$EPEF = \frac{V \cdot BW}{TD \cdot FCR}$$

where:

V – viability (%),
BW – body weight (kg),
TD – trial duration (days).
FCR – feed convertion rate (kg feed/kg gain).

Statistica ver. 13.1.PL was used for the statistical analysis. The normality of the distribution of the random variable was checked using the Shapiro-Wilk test. The significance of the differences between the means was estimated with the Student's *t*-test, and the χ^2 test was used to assess the relationship between the health status of the flocks and the frequency of bird losses (divided into falls and culls) in the subsequent rearing periods.

RESULTS AND DISCUSSION

The data in Table 2 show that the health status of the analyzed flocks had a significant effect on the number of chicken losses during the rearing period, as the values of the χ^2 test in the case of falls, culls, and total losses were significant at $P \leq 0.01$. It was found that the total percentage of losses in the consecutive weeks was higher in the coccidia-infected flock and ranged between 0.38 and 0.94%. The greatest number of losses in this flock (284 chickens, 0.94% of the flock size) was recorded in the first period of 0–7 days. Slightly fewer birds (219, 0.72%) were lost on days 36–42 of rearing. The losses between days 29 and 35 were estimated at 0.54% (164 chickens). The smallest percentage of losses was recorded on rearing days 22–28. The losses reached 117 birds, which accounted for 0.38% of the analyzed group. The total percentage of losses during the 42 days of rearing in the infected group was 3.54% of the entire flock, with 1.59% (517 individuals) of falls and 0.36% (119 individuals) of culls for other reasons. In Ethiopia [Kinung'hi et al. 2004], the mortality rate related to *Eimeria* infections was estimated at 13.3–14.5%, depending on the production scale. In turn, in a study conducted in Great Britain, Blake et al. [2020] reported 2% of chicken falls and culls due to coccidiosis.

In the coccidiosis-free flock, the largest numbers of losses were recorded during the period of 0–7 days, as in the flock infected with *Eimeria* protozoa. The number amounted to 180 chickens, which constituted 0.55% of the analyzed group. The subsequent weeks of rearing were associated with lower cull and fall rates in the flock, i.e. from 0.32% (days 8–14) to 0.26% (days 15–21). The lowest numbers of losses in this flock, i.e. 66 individuals accounting for 0.20% of the group, were recorded on days 29–35.

Body weight and weight gains in individual rearing periods as well as feed intake per 1 kg body weight are important indicators of the effectiveness of broiler chicken rearing (Tables 3 and 4). The analysis of these indicators shows (Table 3) that the growth rate in the chickens from the healthy flock was on average 0.09 kg per 2 days in the first half of rearing (before day 22), whereas a higher rate, i.e. on average 0.10–0.20 kg per 2 days, was noted in the last three weeks (from day 22). Consequently, the broilers from this flock reached a fi-

Table 2. Comparison of losses in the healthy and coccidia-infected flocks throughout the 42-day period with indication of chicken falls and culls

Tabela 2. Porównanie ubytków w stadzie zdrowym i ze stwierdzoną obecnością oocyst kokcydii w okresie 42 dni, z uwzględnieniem upadków i brakowania kurcząt

Age of chickens, days Wiek kurcząt, dni	Falls Upadki				Culls Brakowanie				Total losses Ubytki łącznie			
	HF		IF		HF		IF		HF		IF	
	n	%	n	%	n	%	n	%	n	%	n	%
0–7	149	0.45	135	0.44	31	0.09	149	0.49	180	0.55	284	0.94
8–14	94	0.29	85	0.28	11	0.03	53	0.17	105	0.32	138	0.45
15–21	83	0.25	90	0.29	2	0.01	56	0.18	85	0.26	146	0.48
22–28	78	0.24	65	0.21	22	0.07	52	0.17	100	0.30	117	0.38
29–35	63	0.19	75	0.25	3	0.01	89	0.29	66	0.20	164	0.54
36–42	50	0.15	134	0.44	50	0.15	85	0.28	100	0.30	219	0.72
Total – Ogółem	517	1.59	584	1.94	119	0.36	484	1.60	636	1.96	1068	3.54

χ^2 for falls = 38.06, significant at $P \leq 0.01$; χ^2 for culls = 56.64 significant at $P \leq 0.01$; χ^2 for total losses = 23.36 significant at $P \leq 0.01$.
χ^2 dla upadków = 38,06 wartość istotna przy $P \leq 0,01$; χ^2 dla brakowania = 56,64 wartość istotna przy $P \leq 0,01$; χ^2 dla ubytków łącznie = 23,36 wartość istotna przy $P \leq 0,01$.

Table 3. Mean body weight on consecutive rearing days in the healthy and infected flocks

Tabela 3. Średnia masa ciała kurcząt w kolejnych dniach odchowu w stadzie zdrowym i ze stwierdzoną obecnością oocyst kokcydii

Age of chickens, days Wiek kurcząt, dni	Body weight, kg Masa ciała, kg				Age of chickens, days Wiek kurcząt, dni	Body weight, kg Masa ciała, kg			
	HF		IF			HF		IF	
	x̄	CV	x̄	CV		x̄	CV	x̄	CV
1	0.04	10.35	0.04	11.17	22**	0.99	11.36	0.66	12.61
2	0.06	11.69	0.06	10.36	24**	1.22	12.15	0.93	13.21
3	0.08	10.98	0.07	12.47	26**	1.37	13.33	1.05	14.33
6	0.17	12.24	0.09	12.57	28**	1.57	13.91	1.24	13.97
8	0.22	13.54	0.16	13.57	30**	1.77	12.81	1.31	14.03
10*	0.30	11.23	0.19	13.80	32**	1.90	12.56	1.43	14.12
12*	0.37	10.73	0.26	13.16	34**	2.07	11.87	1.57	14.78
14*	0.44	12.22	0.33	12.63	36**	2.11	11.99	1.72	15.07
16*	0.54	13.11	0.44	14.21	38**	2.21	13.08	1.98	15.02
18**	0.71	10.81	0.52	13.72	40**	2.45	13.27	2.19	15.87
20**	0.81	12.56	0.64	13.45	42**	2.65	13.54	2.23	14.84

Mean values in the group, statistically significant differences: ** at $P \leq 0.01$; * at $P \leq 0.05$; CV – coefficient of variation.
Wartości średnie w grupie; różnice istotne statystycznie: ** przy $P \leq 0,01$; * przy $P \leq 0,05$; CV – współczynnik zmienności.

Table 4. Feed intake in the groups of healthy (HF) and coccidia-infected (IF) chickens

Tabela 4. Spożycie paszy przez krurczęta ze stada zdrowego (SZ) i zarażonego kokcydiami (SK)

Age of chickens, days Wiek kurcząt, dni	Feed intake per body weight gain, kg Ilość spożytej paszy na przyrost masy ciała, kg				Mean feed intake per 1 kg body weight Średnie spożycie paszy na 1 kg masy ciała			
	HF SZ		IF SK		HF SZ		IF SK	
	x̄	CV	x̄	CV	x̄	CV	x̄	CV
1	0.06	10.15	0.06	11.07	1.40	9.23	1.40	10.34
2	0.10	11.89	0.10	10.46	1.50	10.15	1.50	11.26
3	0.12	11.65	0.11	12.51	1.50	11.11	1.60	12.12
6	0.26	11.14	0.14	12.59	1.50	11.45	1.60	12.56
8	0.33	12.94	0.25	13.63	1.50	10.97	1.60	12.07
10	0.45*	10.24	0.30*	13.77	1.50	12.01	1.60	13.03
12	0.56*	10.42	0.42*	13.19	1.50	11.59	1.60	12.08
14	0.66*	12.17	0.52*	12.63	1.60	12.31	1.60	11.37
16	0.86*	12.88	0.70*	14.05	1.60	11.47	1.60	12.03
18	1.13**	10.34	0.88**	13.72	1.60	10.42	1.60	11.54
20	1.29*	12.61	1.11*	13.45	1.60*	11.89	1.72*	12.87
22	1.58**	11.17	1.14**	12.61	1.60*	12.31	1.72*	12.05
24	1.95**	12.08	1.61**	13.14	1.60*	13.11	1.73*	12.09
26	2.19**	13.24	1.82**	14.42	1.60*	12.44	1.73*	13.08
28	2.67**	13.83	2.15**	13.83	1.70	13.76	1.73	14.15
30	3.01**	12.76	2.27**	14.06	1.70*	13.03	1.73*	13.99
32	3.20**	12.30	2.46**	14.14	1.70	12.64	1.72	12.54
34	3.40**	11.70	2.70**	14.84	1.64*	11.23	1.72*	11.13
36	3.60**	11.72	3.01**	15.01	1.71	12.39	1.75	12.49
38	3.80**	13.13	3.47**	15.06	1.72	13.07	1.75	13.47
40	4.05*	13.30	3.83*	15.60	1.65**	10.45	1.75**	11.58
42	4.10*	13.09	3.90*	14.80	1.55**	11.37	1.75**	12.45
Mean feed intake per 1 body weight throughout the rearing period Średnie spożycie paszy na 1 kg masy ciała w całym okresie					1.60*	12.84	1.67*	13.15

Statistically significant differences: ** at $P \leq 0.01$; * at $P \leq 0.05$.
Różnice istotne statystycznie: ** przy $P \leq 0,01$; * przy $P \leq 0,05$.

Table 5. Values of the European Production Efficiency Factor (EPEF) on the consecutive rearing days in the healthy and infected flocks

Tabela 5. Wartości europejskiego wskaźnika wydajności (EWW) w kolejnych dniach odchowu kurcząt w stadzie zdrowym i zarażonym kokcydiami

Age of chickens, days Wiek kurcząt, dni	EPEF scores EWW, pkt		Age of chickens, days Wiek kurcząt, dni	EPEF scores EWW, pkt	
	HF	IF		HF	IF
1	6.80	6.80	22**	147.31	91.63
2	9.52	9.52	24**	181.53	128.12
3	12.70	10.75	26**	203.85	144.49
6*	26.98	13.82	28*	219.87	170.64
8*	34.92	24.58	30**	247.87	180.27
10**	47.61	28.27	32**	266.08	197.93
12**	58.72	39.43	34**	300.49	217.31
14**	65.47	48.51	36**	293.76	233.99
16*	80.35	65.47	38*	305.89	269.36
18**	104.90	77.82	40**	353.50	297.93
20**	119.78	89.14	42**	407.03	303.37

Statistically significant differences: ** – at $P \leq 0.01$; * – at $P \leq 0.05$.
Różnice istotne statystycznie: ** – przy $P \leq 0,01$; * – przy $P \leq 0,05$.

nal weight of 2.65 kg. A lower growth rate was recorded in the chickens from the infected flock. Between the 3rd and 6th day of life, the mean weight of the chickens increased by only 0.02 kg. Hence, after the 6th day of life, the mean body weight of broilers from the flock infected with coccidian oocysts was statistically significantly different ($P \leq 0.05$ or $P \leq 0.01$) in comparison with the body weight of chickens reared in the healthy flock. In the subsequent two-day periods, the chicken growth rate slightly increased, but the weight gains were significantly lower than in the healthy flock. The mean value of this parameter was approx. 0.07 kg per 2 days between days 8 and 22 but increased to approx. 0.14 kg per 2 days from day 22 to the end of the rearing period. Consequently, the final body weight of broilers from the flock infected with coccidian oocysts reached the value of 2.23 kg. It was by 0.42 kg lower than the value noted in the healthy chicken group ($P \leq 0.01$). Györke et al. [2016] reported mean weight gains at the level of 54.8 g per day in *Eimeria* infected flocks, with values ranging from 42.3 to 62.4 g per day per chicken, depending on the size of the flock. As demonstrated by Kipper et al. [2013], broilers infected with various *Eimeria* species achieved 4.6–10% lower body weight gains at a constant feed intake than uninfected birds. As shown by the authors, a 9.5% increase in feed intake in coccidia-infected broiler chickens, compared with disease-free birds, ensures weight gains similar to those in healthy birds. Greater inhibition of growth in *Eimeria*-infected chickens was indicated by Jenkins et al. [2008], who reported that the weight gain in this group of birds corresponded to 48–90% of that in infection-free chickens.

On the first day of life of the chickens, the feed intake in the coccidiosis-free and infected flocks was identical, i.e. 0.06 kg per weight gain and 1.4 kg per 1 kg body weight (Table 4). It was found that the feed intake on the subsequent days of life increased systematically in both flocks. In the healthy flock, it increased from 0.10 kg on the 2nd day of life to 4.10 kg on the last rearing day. The mean feed intake per 1 kg body weight throughout the rearing period in this group was 1.60 kg. In the flock infected with coccidian oocysts, the feed intake vs. the weight gain increased from 0.10 kg on the 2nd day of life to 3.9 kg on the 42nd day. Compared with the healthy flock, the mean feed intake per 1 kg body weight throughout the rearing period of the infected broiler chickens was significantly higher ($P \leq 0.05$) by 0.07 kg and amounted to 1.67 kg. Increased feed intake in chickens with coccidiosis was reported by Kipper et al. [2013]. The authors indicated that birds with multi-species infection as the etiological factor of coccidiosis consumed 5% more feed than control (healthy) birds. In the case of *E. maxima* infection, the increase in feed intake was higher, 8%.

The data collected in both flocks were used for calculation of the European Production Efficiency Factor (EPEF) (Table 5). As reported by Mazanowski [2011], the value of this indicator is mainly influenced by environmental conditions and nutrition. The present study showed that the lowest values were recorded on the first two days of chickens' life. They were the same in both flocks, i.e. 6.80 (1st day of life) and 9.52 (2nd day of life). On the subsequent days, the EPEF in both flocks increased systematically, with higher values calculated for the coccidiosis-free flock. On the 42nd rearing day, the value of the factor was 407.03, which was by 103.66 higher ($P \leq 0.01$) than that in the *Eimeria*-infected flock. In the latter flock, this indicator had substantially lower values throughout the chicken lifespan. These results agree with the findings reported by Haug et al. [2008], who described a significant decrease in EPEF values in flocks with the number of oocysts per gram of feces exceeding 50 000, compared with coccidiosis-free flocks.

CONCLUSIONS

1. The losses of chickens noted during the 42-day rearing period in the coccidia-infected flock amounted to 3.54%, and this value was significantly higher than in the healthy flock. Therefore, greater losses related to chicken falls and culls can be expected throughout the production period in coccidia-infected flocks than in disease-free flocks.
2. From the 6th day of life, the mean body weight of broilers from the infected flock was significantly lower than that of the healthy chickens. The coccidial infection also induced a significant increase in the feed intake per unit of weight gain, reduction of the final body weight, and rearing efficiency associated with the reduced EPEF value.
3. The present results confirm that the presence of parasites from the genus *Eimeria* in the living environment of broiler chickens significantly reduces the rearing efficiency and may worsen the economic outcome on broiler chicken farms. Strict adherence to sanitary procedures throughout the broiler production cycle and limitation of the flock size seem to be the only method for reduction of the extensiveness and intensity of coccidial infection in flocks.

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OCENA PARAMETRÓW ODCHOWU KURCZĄT BROJLERÓW W ZALEŻNOŚCI OD INTENSYWNOŚCI ZARAŻENIA PIERWOTNIAKAMI Z RODZAJU *EIMERIA*

STRESZCZENIE

W pracy oceniono parametry odchowu kurcząt brojlerów Ross 308 w zależności od intensywności zarażenia pierwotniakami z rodzaju *Eimeria*. W analizie uwzględniono dwa stada. Jedno uznane było za wolne od kokcydiozy (SZ), a drugie (SK) zakwalifikowane było jako stado zarażone. Zebrane dane obejmowały: wiek kurcząt, ubytki (w tym upadki i brakowania), masę ciała i wielkość przyrostów oraz dobowe zużycie paszy. Oszacowano także średnie spożycie paszy na 1 kg masy ciała i wyliczono wartość europejskiego wskaźnika wydajności (EWW). Badania wykazały, że obecność pasożytów z rodzaju *Eimeria* w środowisku życia kurcząt brojlerów wpływała na efektywność odchowu poprzez zwiększone zapotrzebowanie na paszę oraz wyższy odsetek upadków i brakowań w okresie ich odchowu, w porównaniu z kurczętami odchowywanymi w stadach wolnych od kokcydiozy. U kurcząt zarażonych kokcydiami, mimo że przyjmowały więcej paszy, obserwowano znacznie wolniejszy przyrost masy ciała. EWW w 42. dniu odchowu brojlerów ze stada uznanego za zarażone *Eimeria* był o 103,66 niższy w porównaniu z wyliczonym w stadzie zdrowym.

Słowa kluczowe: kurczęta brojlery, kokcydia, spożycie paszy, EWW, efektywność odchowu

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