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RESEARCH ARTICLE

Influence of Claw Disorders on Milk Production in Simmental Dairy Cows

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Abstract

A study on claw disorders' influence on milk production was performed during one year on 226 Simmental loose-reared cows. The first trial group included 42, the second 37, and the third 34 cows, with claw changes observed in the first hundred days of lactation, between days 101 and 200, between days 201 and 305, respectively. The control group included 113 cows with no observed changes. Lameness intensity was assessed once a week. Milk yield data were collected three weeks before, in the week of treatment of claws and three weeks afterwards. There were significantly more cows with lameness in the third group than in the other two groups, as well as the most cows with one affected limb in the first hundred days of the lactation ($P<0.05$). Significantly fewer cows with two affected limbs were present in the first group. In the second group, more cows were observed with two affected limbs than in the first group ($P<0.05$). In the third group, more cows with three or four affected limbs were noticed than in the other groups. The most common claw disorders were: solar ulcer, laminitis, dermatitis digitalis and overgrown claws. Cows whose claws were affected between days 101 and 200 of lactation period produced 231 kg less milk than those of the control group; cows whose claws were affected in the last third of lactation produced 26 kg less milk. Nevertheless, no significant differences were found between milk yields of the control and trial groups ($P>0.05$). Cows affected in the first third of lactation produced less milk (324 kg) than both healthy and cows with claw changes manifested in later stages of lactation. Obtained data confirm that claw disorders may affect dairy production.

Keywords: *Claw disorders, Cow, Lameness, Milk production, Simmental*

Simental Süt İneklerinde Tırnak Bozukluklarının Süt Üretimine Etkisi

Öz

Açık sistem yetiştiriciliğinin yapıldığı 226 Simental inek üzerinde bir yıl boyunca tırnak bozukluklarının süt üretimi üzerine etkisine yönelik bir çalışma gerçekleştirildi. Birinci deneme grubu, laktasyonun ilk yüz günlük döneminde olan ve tırnak değişiklikleri gösteren 42 inek; ikinci grup, laktasyonun 101 ile 200. günleri arasında olan ve tırnak değişiklikleri gösteren 37 inek ve üçüncü grup, laktasyonun 201 ile 305. günleri arasında olan ve tırnak değişiklikleri gösteren 34 inekten oluşuyordu. Kontrol grubunu hiçbir tırnak bozukluğu gözlenmeyen 113 inek oluşmaktaydı. Topallık yoğunluğu haftada bir değerlendirildi. Süt üretim verileri, tırnakların tedavisinden önceki üç haftalık dönem, tedavini yapıldığı hafta ve tedaviden sonraki üç haftalık dönemlerde toplandı. Diğer iki gruba göre üçüncü grupta topallık gösteren inek sayısı çok daha fazlaydı ve bir ayağı etkilenmiş ineklere en fazla laktasyonun ilk yüz günlük döneminde rastlandı ($P<0.05$). İki ayağı etkilen inek sayısı birinci grupta önemli ölçüde daha azdı. Birinci gruba oranla ikinci grupta iki ayağı birden etkilenen inek sayısı daha fazlaydı ($P<0.05$). Üçüncü grupta ise diğer gruplara oranla üç veya dört ayağı etkilenmiş inek sayısı daha fazalydı. En yaygın tırnak bozuklukları; taban ülseri, laminitis, dermatitis digitalis ve aşırı tırnak uzamasıydı. Kontrol grubu ile kıyaslandığında, laktasyonun 101 ile 200. günleri arasında yer alan ve tırnak bozukluğu olan inekler 231 kg daha az süt üretirken, laktasyonun son üçte birlik kısmında yer alan ve tırnak bozukluğu olan inekler ise 26 kg daha az süt üretmiştir. Bununla birlikte, kontrol ve deneme gruplarının süt verimleri arasında önemli bir fark saptanmamıştır ($P>0.05$). Laktasyonun ilk üçte birlik döneminde bulunan inekler, hem kontrol hem de laktasyonun sonraki dönemlerinde bulunan ve tırnak bozukluğu olan ineklere oranla daha az (324 kg) süt üretmiştir. Bulgular, tırnak bozukluklarının süt üretimini etkileyebileceğini doğrulamaktadır.

Anahtar sözcükler: *İnek, Tırnak bozukluğu, Topallık, Simental, Süt üretimi*

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Introduction

Lameness caused by claw disorders is one of the most important diseases in modern dairy cattle production world-wide [1,2], causing pain, distress, weight loss, decreased milk production and reproductive performance, increased risk of culling and treatment costs and death [2,3]. This condition occurs as a result of many causes and predisposing factors ranging from the environmental conditions to the individual factors of the dairy cattle [1,4,5]. Claw disorders are characterized by intensity, a number of affected limbs and disease characteristics. An important predisposing factor for lameness is claw overgrowth [1,3,4], particularly in combination with hard flooring surfaces and weight bearing disturbances. The most significant causes of hoof overgrown in cows are genetic predisposition, insufficient movement of animals, inadequate nutrition, and untimely hoof trimming. Overgrowth of the hoof leads to deformation of the hoof horn, exposure of the soft parts of the hoof, development of degenerative and inflammatory processes, all of which contribute to the appearance of claw disorders. There are many risks for lameness, including season, gestation and stage of lactation, previous disease and parity, as well as a genetic determined intrinsic risk for development of claw lesions [5]. Generally, the incidence of lameness in dairy cows has been approximately 25%, ranging from 1 to 55% [6,7]. According to literature data, the most prevalent claw disorders in intensive dairy farming are digital dermatitis, sole ulcer, white line disease, toe necrosis and sole hemorrhage [8,9].

There is a growing amount of evidence worldwide regarding the impacts of lameness on milk yield in dairy cows, and numerous studies have been conducted from different viewpoints [10-15]. According to Kibar and Çağlayan [16], the shape of the lactation curve is influenced by herd factors such as management and nutrition and individual factors like genetics, parity, and disease. Discrepancies in the literature regarding to the effect of lameness and claw lesions on milk yield are partly the result of these complex influences. Comprehensive literature data regarding the impact of claw disorders on milk production in Serbia were presented by Hristov et al.[2]. The loss of milk of 1.7-3.0 L/day occurs up to one month before and one month after the treatment due to pain. According to Greenough [9] the financial impact of claw disorders includes losses from decreased production, cost of treatment, prolonged calving interval, and possibly nursing labour. The study of Charfeddine and Pérez-Cabal [17] demonstrated that claw disorders have an important effect on the production and performance of cows. Cases of dermatitis, sole ulcer and white line disease reduce milk production, led to longer days open intervals, and decrease productive life.

In this study, the hypothesis was that not only the incidence of claw disorders and treatment significantly affect the milk production, but the intensity of lameness of lactating cows may be correlated with a decrease in milk yield, a number of affected limbs, types of diseases and lactation period when lameness occurs as well. To test this, the frequency distribution of the intensity of lameness, number of affected legs, types of diseases and treatment results were examined in different stages of lactation in relation to the milk yield.

Material and Methods

The study was carried out on a dairy farm with 320 Simmental loose-reared cows during one year. The claws of all cows were weekly observed for lameness and those that were found to be affected were treated by veterinarians. A total of 226 of 320 cows on the farm were used.

There were 113 cows without changes (control group) and 113 cows in three groups of affected cows with claw changes (including overgrown claws). The affected cows were divided in three groups regarding the period of lactation when changes were noticed and the therapeutic treatment also was performed. There were 42 cows in the first (1st) trial group with claw changes observed in the first 100 days of lactation. In the second (2nd) trial group there were 37 cows with claw changes manifested between days 101 and 200 of lactation, and the third (3rd) trial group was formed of 34 cows with claw changes noticed between days 201 and 305 of lactation.

According to needs of current phisical conditions (body mass, parity, milk production and phase of lactation), cows were fed using five total mixed rations (TMR) with 17.57%, 22.57%, 21.61%, 22.28% and 25.20% of dry matter, 2764.65 g, 3542.27 g, 3339.87 g, 3669.33 g and 3961.99 g of crude protein, and 104.77 MJ, 145.07 MJ, 136.11 MJ 150.81 MJ and 171.03 MJ of net energy content, respectively. In preparation of TMR was used corn silage, alfalfa hay, pea hay, peas and alfalfa, soybeans, semolina, sunflower meal, beetroot pulp, corn grains, dried fodder peas grains and mineral-vitamin supplement. Rations were delivered by vertical mixer trailer, once a day, in the amount of 24 h. The cows consumed water *ad libitum* due to automatic heated water througs. Floors were made of cement and cleaned by manure scrapers were used on daily bases, and lying areas were recovered with saw dust when neccesary. The stall was equiped with fans for cooling and additional ventilation. Preventive hygiene measures prescribed by the Veterinary Law and the Program of animal health protection measures took place.

Lameness intensity was assessed once a week according to the Whay et al.[18], modified by Berry [19], on the concrete floor in a narrow corridor. On the day of lameness diagnosis, lameness intensity, number of affected limbs, the character of claw diseases were determined and therapeutic claw treatment were applied to all cows. Milk yields for the control groups divided into three periods corresponded

to the same periods used for three trial groups. Milk yield data were collected using the software of computerized milking parlor Westfalia SARD-C21 and by recording amounts of raw milk obtained three weeks before, in the week of therapeutic treatment of claws and three weeks after treatment. Daily milk yields were recorded and average milk yields for three phases of lactation (days 1 - 100, 101 - 200 and 201 - 305) were established and analyzed with respect to the standard lactation curve and time of claw changes occurrence. Correlations between lameness parameters, such as lameness intensity, number of affected limbs, character of claw disorder, time of claw treatment and milk yield were calculated.

All statistical analyses were performed by Statgraphics centurion XV [20]. Descriptive statistics, Pearson's product-moment correlation coefficient and ANOVA-analysis was performed regarding correlations between lameness intensity, the number of affected limbs, the character of claw disorder and time of claw treatment, and milk yields at the time of treatment. The research took place in compliance with the Serbian Law on Animal Welfare (Official Gazette of the Republic of Serbia, No. 41/09) and Ordinance on the conditions for registration for trial animals and the keeping of such a register, training programs on welfare for trial animals, request forms for approval of conducting experiments on animals, keeping, treatment and killing trial animals and reproduction, circulation, or implementation experiments on animals (Official Gazette of the Republic of Serbia, No. 39/10).

Results

In *Fig. 1*, *Fig. 2* and *Fig. 3* the distribution of lameness intensity, number of affected limbs and types of claw disorders, respectively, of all examined trial groups of cows regarding the period of lactation were presented.

Different grades of lameness intensity were noticed during all lactation periods *(Fig. 1)*. It may be noted that the number of the cows without the lameness decreased, the number of the cows with a mild form of lameness slightly variated, while the number of cows with moderate lameness increased with respect to the lactation period. The smallest number of cows in all three lactation periods was with a severe form of lameness. Less cows without lameness were found in the 3rd trial group ($P<0.05$), and more cows with a moderate form of lameness were found in the 3rd trial group than in both the 1st and the 2nd trial groups ($P<0.05$).

Regarding the number of affected limbs *(Fig. 2)*, most cows of the 1st trial group had one affected limb in the period of lactation until day 100 (20 cows), which was significantly more than in the other two groups ($P<0.05$). The occurrence of the disease in two or three limbs increased as lactation progressed, since the lower lameness occurrence rate observed in cows with two claws affected in the first hundred days of lactation. There were significantly more cows with three or four affected limbs in a period of 201 to 305 days than in earlier periods. Regarding diseases of

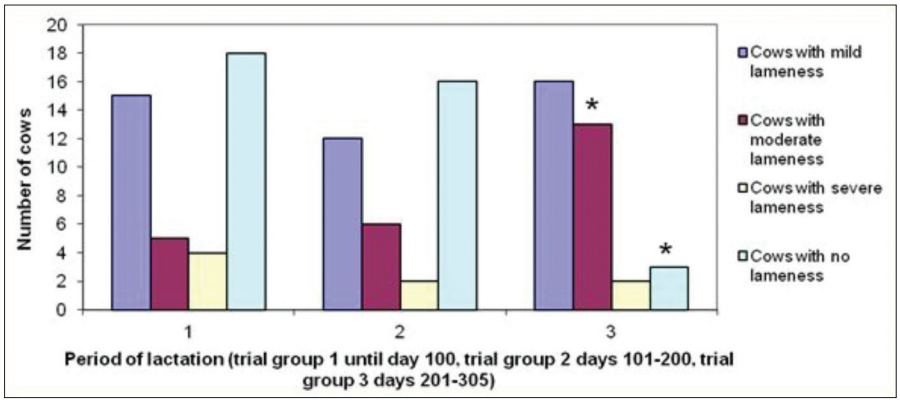
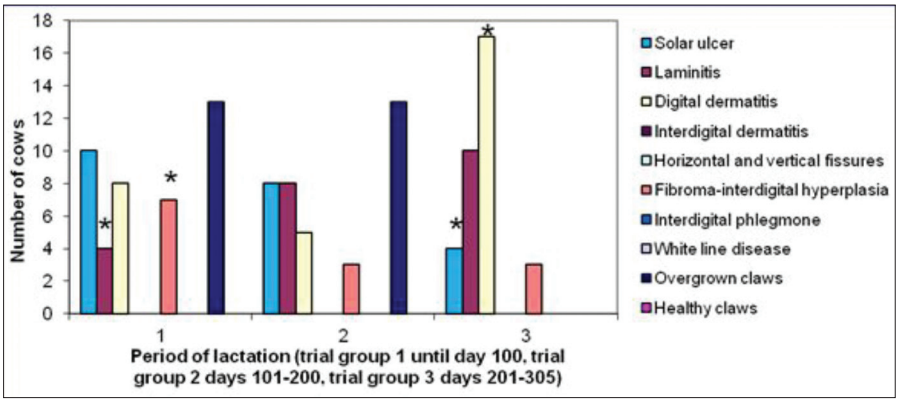


Fig 1. Lameness intensity distribution in trial groups regarding the period of lactation

Fig 2. Distribution of cows according to the number of affected limbs during different periods of lactation



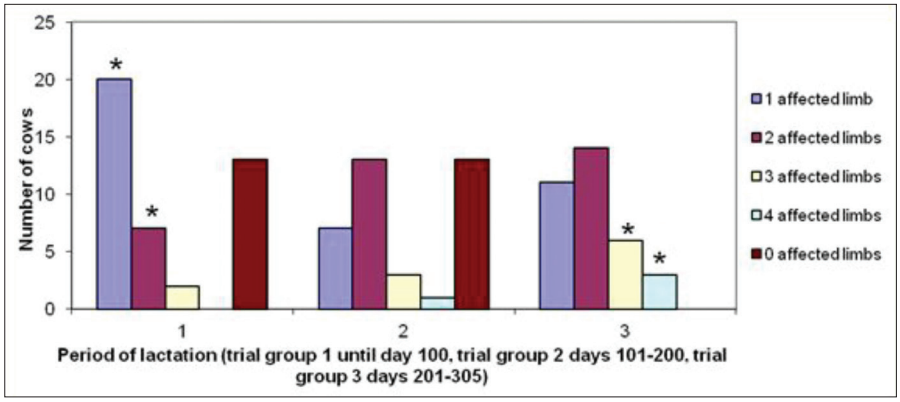


Fig 3. Distribution of cows in trial groups regarding the type of claw disorder

Fig 4. Lactation curves of three trial groups of cows

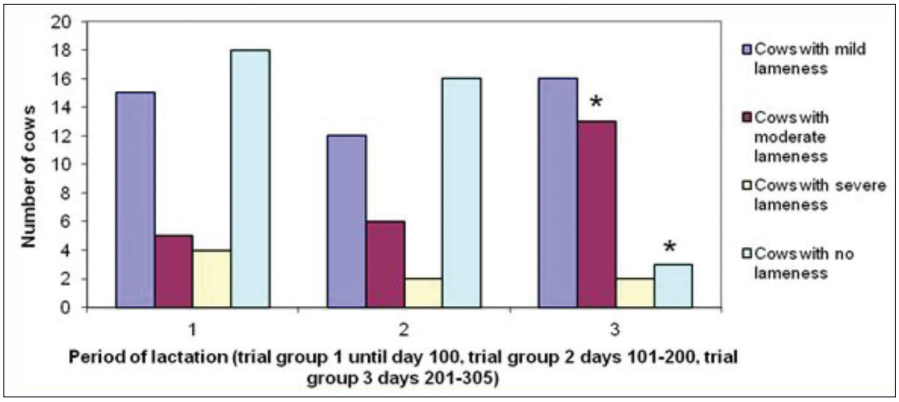


Table 1. *Milk production of cows with and without claw disorders*

Lactation Period, Days	1st Trial Group (days 1-100) (n=42)				2nd Trial Group (days 101-200) (n=37)				3rd Trial Group (days 201-305) (n=34)			
Days after correction	day of correction	7	14	305	day of correction	7	14	305	day of correction	7	14	305
Control group, $\bar{x}$/cow, kg	22.69 x^{-}	23.24	23.60	6057	19.91	20.81	20.86	5970	19.21	19.25	19.26	6056
All three trial groups, $\bar{x}$/cow, kg	21.96	22.3	21.95	5733	19.37	19.87	19.43	5739	18.45	18.77	18.34	6030
Statistical significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

ns: *P>0.05; * P<0.05; ** P<0.01*

the front or the hind limb, it was observed that more cows (65 cows) had pathological changes on hind limbs than on front limbs (6 cows). Both affected hind limbs were noticed in 34 cows, while 31 cows had one hind limb affected. In addition, 42 cows underwent changes on both front and hind limbs, with 18 of them having some claw changes and 24 cows with overgrown claws.

The type of claw disorder varied significantly amongst groups *(Fig. 3)* and was related to the period of lactation. The most common claw disorders in our study were solar ulcer, laminitis, digital dermatitis and interdigital fibroma.

Fig. 4 clearly demonstrates that lactation curves of the trial groups differed from the standard lactation curve.

In the 3rd trial group, lower production of milk was determined in the first four months of lactation than in the 1st and 2nd groups. In the fifth month of lactation, the milk yields of all trial groups were almost equal. From the middle to the end of the lactation period, higher milk yield was determined for cows of the 3rd trial group.

According to *Table 1*, cows whose claws were affected between days 101 and 200 of lactation period produced 231 kg less milk than those of the control group, and cows whose claws were affected in the last third of lactation produced 26 kg milk less than those of the control group. Nevertheless, no significant differences were found between milk yields of the control and trial groups (P>0.05). Cows that were affected in the first third of lactation produced less milk (324 kg) than both healthy cows and cows with claw changes manifested in later stages of lactation.

According to the results presented in *Table 2*, there was no significant difference between milk yields three weeks before and three weeks after claw treatment.

Table 2. *Daily milk yield with respect to time of claw correction*

Daily Average Milk Yield, kg	3 Weeks Before Correction	In the Week of Correction	3 Weeks After Correction	Influence of Correction	LSD-Test
1st group, $\bar{x}$	21.43±5.73	21.96±5.63	22.03±5.61	ns	ns
2nd group, $\bar{x}$	19.85±5.63	19.37±4.74	19.4±4.29	ns	ns
3rd group, $\bar{x}$	19.57±4.66	18.45±5.08	17.8±5.44	ns	ns
Influence of the period of lactation	ns	ns	ns	ns	ns
LSD-test	ns	ns	1st group : 3rd group P<0.05	ns	ns

ns: *P>0.05; * P<0.05; ** P<0.01*

Table 3. *Correlations between lameness parameters and milk yield*

Parameters	Lameness Intensity	Number of Affected Limbs	Character of Disorders	Time of Correction
Milk yield 3 weeks before correction	0.0062	-0.1083	0.0826	-0.0930
Sample size, n	113	113	113	113
P-value	0.9481	0.2534	0.3845	0.3274
Milk yield in the week of correction	-0.0927	-0.2192	0.1260	-0.2795
Sample size, n	113	113	113	113
P-value	0.3287	0.0197*	0.1837	0.0027**
Milk yield 3 weeks after correction	-0.0217	-0.1893	0.1467	-0.3318
Sample size, n	113	113	113	113
P-value	0.8197	0.0446*	0.1210	0.0003**

ns: *P>0.05; * P<0.05; ** P<0.01*

Three weeks after the treatment of claws, the difference was significant between groups 1 and 3 (22.0 kg and 17.8 kg, respectively), due to a physiological drop of milk production in the last third of lactation having in mind for standard lactation curve and lactation persistence.

Milk yield of cows with claw disorders was lower compared to ones with no claw disorders two weeks after the treatment in all three phases of lactation (1.65 kg, 1.43 kg, and 0.92 kg, respectively).

Correlations between lameness parameters and milk yield are presented in *Table 3*. The significant negative correlation between milk yield and the number of affected limbs (P<0.05; r=-0.2192 and r=-0.1893) was found, as well as a very significant negative correlation between milk yield and time of claw treatment (P<0.01; r=-0.2795 and r=-0.3318) in the week of treatment and three weeks later.

Discussion

The obtained results show that different types of lameness in dairy cows occurred during all three lactation periods, while its intensity changed during lactation. The study results are in accordance with literature data regarding etiology, time and frequency of major claw diseases [21].

Analysis of distribution of cows regarding to the affected limbs occurrence during lactation showed that disease in two or three limbs increased as lactation progressed, since the lower lameness occurrence rate observed in cows with two claws affected in the first hundred days of lactation. Certain disease manifestations (laminitis, white line disease, e.g.) on more cow limbs require more time to develop [22]. Claw disorders findings during the last third of lactation indicate that there was sufficient time to develop clinical manifestations which will last longer in a number of limbs. According to Greenough [22], claw diseases cannot be diagnosed timely, so they may influence health and production for a long time, which is in line with our results as a whole.

Related to the period of lactation, the most common claw disorders in performed study were solar ulcer, laminitis, digital dermatitis and interdigital fibroma. The occurrence of the solar ulcer decreased while the incidence of laminitis increased as the lactation progressed. Digital dermatitis was significantly more prevalent in the last third of lactation. The occurrence of overgrown claws was observed during the first two thirds of lactation, while later was not recorded. Obtained results are in accordance with literature data [5,8,23]. Most claw diseases occurres in the time of calving [16]. Claw diseases, such as white-line disease, sole ulcer, and hemorrhages, become visible after 2 to 3 months. These cows eat less; they are more reluctant

to move and might consequently produce less milk than cows without claw lesions.

In the fifth month of lactation, the milk yields of all trial groups became almost equal. From the middle to the end of the lactation period, higher milk yield was determined for cows of the third trial group. The larger decline in milk production at the beginning of the second third of lactation coincided with the occurrence of claw disorders. These results show that the earlier occurrence of claw disorders during lactation has more apparent influence on the reduction of the milk yield compared to the later occurrence. Hernandez et al.[11] found that during lactation, 31% of cows were affected with lameness caused by claw lesions (60%), papillomatous digital dermatitis (31%) or interdigital phlegmon (9%). Consequently, milk yield of lame cows with interdigital phlegmon was significantly lower (10%). Lame cows with papillomatous digital dermatitis produced less milk than healthy cows, but the difference was not significant. Similarly, there was a linear relationship between milk yield and different increasing grades of lameness of dairy cows and decreasing milk yield among cows in their second or later lactations [12]. Amory et al.[13] investigated the effect of lesion-specific causes of lameness, based on farmer treatment and diagnosis of lame cows, such as solar ulcer and white line disease. Their results highlight that specific types of lameness vary between and within herds, associated with higher-yielding cattle [14,24]. Results of Correa-Valencia et al.[25] study confirmed these findings, who found that non-infectious foot lesions were more common than infectious (94.4 *vs.* 5.6%), white line disease was more frequently observed in the hind limbs (79.6%) and more frequent in medial claws of the front limbs (70.3%). In hind limbs, the lateral claws were more commonly affected (65.7%). The significant associations between most claw disorders and decreased yield do not prove direct relationships in the study of Kibar and Çağlayan [16]. Different aspects of the impact of lameness on milk production have been investigated by many authors. For instance, it was established that summer season foot lesions were more severe than winter season lesions, regardless of the stage of lactation [5,6]. Also, our study revealed that milk production, when foot lesions occurred, was a determining factor of the amount and pattern of milk loss only for cases during mid to late lactation [10]. The positive impact of the claw treatment was visible in the control group of cows, where the first two weeks after treatment and even in the last third of lactation an increase in the milk yield was noticed. In this study, cows with claw disorders produced less milk than those with no claw disorders two weeks after the claw treatment in all three phases of lactation. Obtained study results are in line with the literature data [10,15,26].

The significant negative correlation between milk yield and the number of affected limbs was found, as well as a very significant negative correlation between milk yield and time of claw treatment in the week of treatment and three weeks later are consistent with the data presented by Kos et al.[27], confirming that overgrown claws are fairly common during the first two thirds of lactation. Overgrown claws are one of the major factors in claw damage and lameness development, but well-timed treatment in the initial period of disease could decrease production loss [28] and increase milk yield in the following lactation stages, as it was observed in our study.

The lactation curves of the three trial groups of cows revealed differences between milk yields in different periods of lactation, indicating that the occurrence of claw disease impacted milk production and changed the shape of the lactation curve. Also, cows with affected claws during the first period of lactation had lower milk production compared with the control group. The most likely explanation for this may be that claws are particularly susceptible during partus and at the beginning of lactation [29]. According to Ristevski et al.[21], high milk production is related to lameness occurrence. Cows with claws that manifest disease later have lower milk production in the early period of lactation, which was also found in our research. According to Charfeddine and Pérez-Cabal [17], severe lesions were less frequent by far, but typically led to economic losses three times greater than those associated with mild lesions. Data on lesion incidence and economic costs could be used to develop farm-based decision support tools that could assist farmers to tackle lameness issues on their farms in the most cost-effective manner. Results in the study are also consistent with the study results of Onyiro et al.[30], who found that poor locomotion was associated with a significant reduction in the milk yield of later lactation cows. There was a significant difference in the shape of the lactation curve depending on whether or not the cow was lame during lactation [16]. Studying an impact of mobility score on milk yield and activity in dairy cattle, Reader et al.[31] noted that lame cows had a reduced milk yield, both before and after they were treated. The cows activity was significantly lower with increasing mobility score; the associations between activity and parity and month of lactation were larger, indicating that once cows were lame, they remained lame or became lame again despite treatment, so they concluded that cows started to produce less milk before their mobility was visibly impaired, which is an acceptable explanation for our results. According to Ristevski et al.[21], milk production is an important lameness risk factor, since that high milk production and low or high BCS are important for developing chronic lameness, as well as that the interaction between milk production, a BCS and metabolic parameters poses a higher risk for developing chronic lameness in dairy cows in comparison with the exposure to a single risk factor.

Cows affected during the first third of the lactation revealed a greater reduction of milk yield than cows which were affected later. A positive effect of claw treatment could be

seen between the first and the second third of lactation when cows of the 1st trial group produced more milk than other cows. As an immediate treatment followed the diagnosis of claw disorder, a favorable effect of claw treatment occurred through an increase of milk production in the second period of lactation, like in other studies [28]. Results obtained in this study are consistent with literature data [16,32] confirming that factors such as poor conditions of rearing, social and hierarchical relationship problems, presence of other diseases, such as claw diseases, which for some reason cannot be observed timely and are sometimes present in the initial period of lactation, may reduce milk production during that period, but later, with the cessation of their impact, milk production usually increases [22]. Regardless of the cause, these cows do not achieve the genetic potential for the quantity of produced milk without spending metabolic reserves, and in the later periods of lactation, consequently, an increase in milk production follows. In addition, according to Alvergnas et al.[33], the most efficient strategy seems to be early detection and diagnosis, hygiene of floors and bedding, and proper diet to avoid any ruminal acidosis or BCS drop.

According to data about influence of claw disorders on milk production presented in this study, different lameness intensities were observed during all periods of lactation. A significantly higher number of cows with a moderate form of lameness were found in the last third of lactation. Cows affected in the first third of lactation had lower milk production than both healthy cows and cows with claw changes manifested in later lactation stages. All presented data confirm that claw disorders may affect dairy production of Simmental cows.

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Conflict of Interest

The authors confirm no conflicts of interest regarding this manuscript.

Author Contribution Statement

Z. Zlatanović and S. Hristov conceived and planned the experiments. Z. Zlatanović, S. Hristov and B. Stanković carried out the experiments. Z. Zlatanović, S. Hristov, B. Stanković, M. Cincović, D. Nakov and J. Bojkovski contributed to the interpretation of the results. S. Hristov took the lead in writing the manuscript. All authors provided critical feedback and helped shape the research, analysis and manuscript.

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