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Determination of the physical properties of different types of milk claws and air leaks in the claw according to rotameter-milk bucket methods

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Abstract. In this study, physical properties (internal volumes, weight and the diameters of the hole in the milk and pulse tubes) of eighteen different types of milk claws which are one of the significant components of milking machine and the amount of air leaks in the claws were examined according to the flow meter (rotameter) and milk bucket experiment methods. 'L' type milking claw was 70 ml in volume which was lower than the standard minimum volume of 80 ml, however, others were higher. Five of the claws ('C', 'D', 'E', 'H' and 'Q' types of claws) were lower than 500 g, the minimum recommended standard for weight. Internal diameters of the short milk tube of the claws were between 5.5 and 10.8 mm. Internal diameters of all but one of the claws' main milk output tubes (with a diameter of 11. 9 mm in 'L' type) were under the minimum diameter (12.5 mm).

In experiments conducted with rotameter, the values of the leaking of the claw tap were between 0.0 and 11.0 l min^{-1}. Air leakages of twelve claws ('A', 'C', 'E', 'F', 'H', 'I', 'J', 'K', 'L', 'N', 'P' and 'R' types of claws) were below the standard maximum level of 2 l min^{-1}. The amounts of leaks in the tap of claws were between 0.0 and +14 l min^{-1}. Ten milk claws in here ('A', 'B', 'C', 'D', 'F', 'G', 'M', 'O', 'P' and 'R' types of claws) did not meet the minimum and maximum flow rates. The total amounts of air leak in the claws in the experiments performed with a milk bucket were between 4.1 and 33.9 l min^{-1}. Although the calculated amount of total air leak in all the claws was above the recommended minimum amount (4 l min^{-1}), eight claws ('B', 'C', 'D', 'E', 'H', 'J', 'K', and 'O' types of claws) exceeded the maximum limit (12 l min^{-1}).

Key words: Milking machine, milk claw, claw physical properties, rotameter, milk bucket, claw air leak, free air intake hole leakage.

INTRODUCTION

Milk claw is an element that ensures the collection of the milk in milking machines coming from milking cluster to milk bucket or milk pipeline. Claw generally consists of a vacuum inlet coming from the pulsator, the section that transmits the vacuum to teatcup, the inlet of the milk coming from the teatcupliner, the output that ensures the transmission of the milk to the milk bucket or pipeline, and the claw valve that is used in order to stop the flow of the milk when necessary. The body of the milking claw generally consists of plastic and stainless material, and the upper part is made of transparent plastic. The short milk and pulse tubes between the milking claw and teatcup liner are made of rubber, and the tubes between the milking claw and the main milking tube are made of PVC. Today, the volume of the milking claw may be of different capacities depending on milk yield. While the claw capacity depends on the milk yield of the animal, tube with a small volume are preferred in bucket milking machines, and tube with a large volume are preferred in pipeline milking machines (Akam et al., 1990; Mein, 1992; Unal, 2013).

Commercially, the weight of the existing milking cluster varies between 1.6 and 3.5 kg. The weight of the milking clusters used in New Zealand may usually be between 2.2 and 2.6 kg. The real benefit of the milking cluster is that it ensures that the milk is discharged in a short time with the pressure effect it applies on the teat of the animal. However, the increase in the weight of the milking cluster has disadvantages such as the tiredness of the milker, slipping of the teatcup liners, falling off the teat-end, and damaging the teat-end. The optimum weight selection is generally determined by the type of teatcup liner used and the vacuum setting preferred (Dairynz, 2015).

According to ISO 5707, the total air inlet per each milking cluster is suggested as at least 4 l min^{-1} in order to allow effective milk transmission through the claw and prevent the additional mixing of the milk in the claw. This value should not exceed 12 l min^{-1} for cows and buffalos, and 8 l min^{-1} for sheep and goats in a nominal working vacuum. When the vacuum closing valve of the milking claw is in off position, the free air flow into the long milk tube should not be higher than 2 l min^{-1}. The leaktightness of the vacuum closing valve of claw is important when removing the milking cluster. If the claw valve is not or cannot be closed well when the milking ends, the milking clusters are removed by pulling manually as its vacuum effect on cluster will continue (as the valve fails to cut the vacuum completely). This is an unwanted situation for the milking technique. Furthermore, the free air flowing from the valve leads to the failure to obtain enough vacuum in the claw and teat-end. Thus, all air holes leakages on the claw should be positioned so as to prevent unnecessary turbulence in the milk in order to prevent free fatty acid formation during milking. There is an air inlet hole with a diameter of approximately 0.8 mm on the claw in order to facilitate that milk is transmitted to the bucket or pipeline from the long milk tube. Constant air inlet is ensured from this hole on the claw (ISO 3918, 1996; Bilgen & Oz, 2006; Unal 2013; TS ISO 5707, 2014; TS ISO 6690, 2014; Dairynz, 2015).

In the research conducted, no comprehensive study was encountered on the air leakage amounts of the claws both by physical properties and flow meter (rotameter) and bucket experiment methods of different types of milk claws in our country and the world.

The objective of this study was to determine certain physical properties (internal volumes, weights, milk and pulse tubes hole diameters) that are accepted as effective elements on the milking performance and milk quality of eighteen different types of milk claws that are locally produced and used all around the world and the air leakage amounts of the claws by rotameter–bucket methods (claw valve leaktightness, amount of claw valve leakage, total amount of air leakage passing through the claw and the amount of air entering the claw free inlet hole).

MATERIALS AND METHODS

Eighteen different types of milking claws used in bucket and pipeline milking machines and facilities were investigated in this study (Fig. 1).

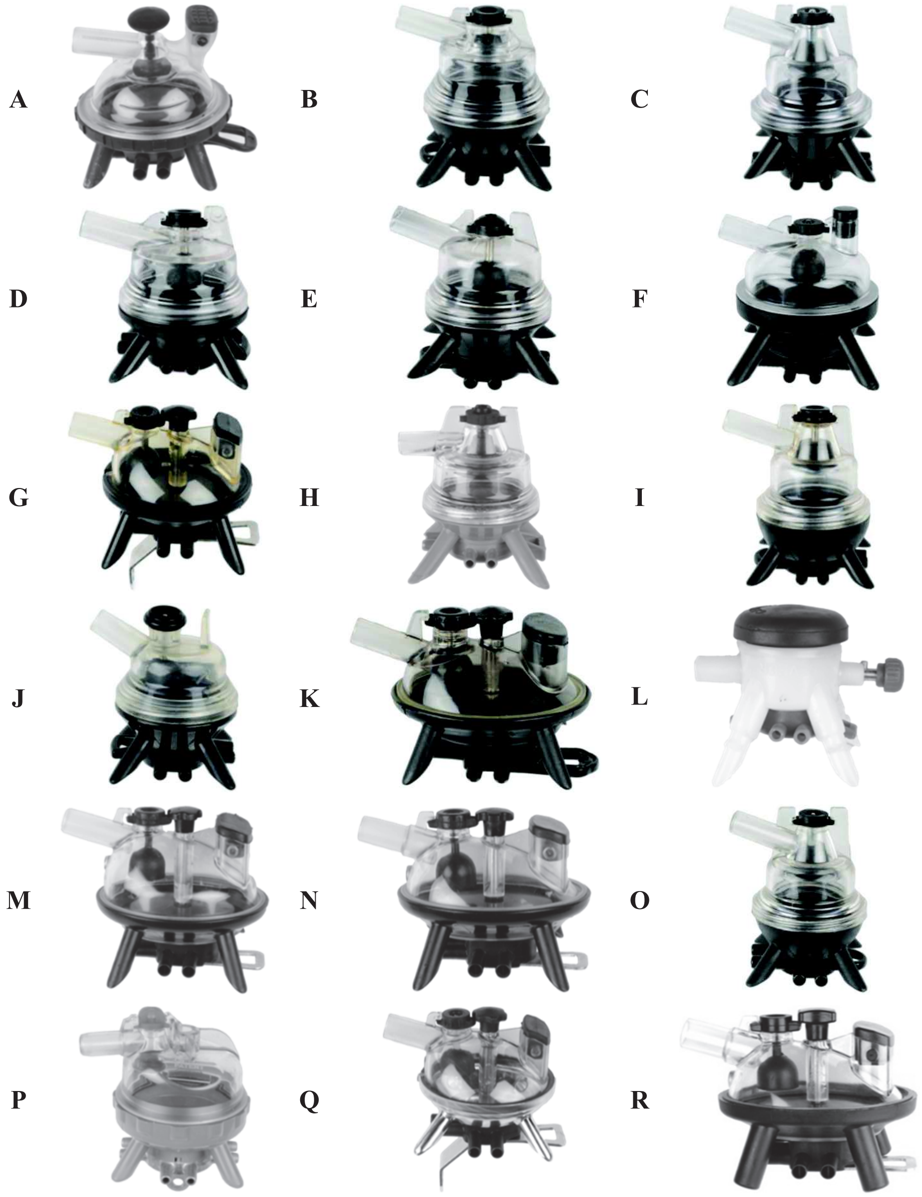

Figure 1. Eighteen different types of milking claws used in the research.

The internal volumes, weights (milking claw and milking cluster as a whole), the internal diameters of short milk inlet and main milk output tubes and the internal diameters of short and long pulse tubes were measured respectively in order to reveal the physical properties of the milking claws. The capacities of the claws were determined in accordance with the amount of water filled into their internal volume. For this, the openings of four short milk inlet tubes of the milking claw were closed hermetically, and water was filled in the claw from the opening of the main milk output. At that moment, the claw valve was kept in the open position and the rubber tab was kept on the claw at a tight contact. The water that was filled at claw capacity was then poured into a container with levels with a capacity of 500 ml, and the volume of the claw was found in millilitres (ml). The weights of the claws were weighed using scales with a sensitivity of 1 g (Baster B 150, Capacity: 15 kg, İzmir, Turkey) as a milking cluster only on the claw and the whole claw. The milk and pulse tubes internal diameters of the claws were measured with a digital calliper (Mitutoyo, CD-15CP, USA) with a sensitivity of 0.01 mm.

In this research, a vacuum pump with an air capacity of 200 l min^{-1} (1,425 rpm and 50 kPa working vacuum) with a direct connection to the electricity motor of 0.55 kW for the vacuum production necessary for the measurement of milking claw air leakage was used. The vacuum pump was adjusted to nominal vacuum pressure (50 kPa) throughout the works.

Flow meter and a stainless steel milk bucket with a volume of 20 l were used for the leaktightness of the claw valve, and the leakage amount measurements of free air inlet hole in this study. The rotameter (Flowmeter, AGL 19, Medition,Spain) has a flow measurement interval between 0.0–14.0 l min^{-1} and a measurement sensitivity of 1.0 l min^{-1}. The vacuum changes in the measurements made with the bucket were monitored with a digital vacuum meter (DVPM-01 Digital Vacuum Pressure Meter, Medition, Vacuum and Pressure Range 0–100 kPa) with the sensitivity of 0.1 kPa, and the pressure change periods were monitored on digital chronometer.

The claw vacuum closing valve leaktightness is the unwanted air leakage entering from the claw valve. This leakage measurement is determined only through the rotameter (Bilgen & Oz, 2006). For the measurement, the rotameter device was connected to the milking claw with the long milk tube on the one side, and to the vacuum line with a secondary tube on the other side. The claw vacuum closing valve leaktightness was measured when the milk inlets of the claw were open, and the claw valve was in the closed position (Fig. 2). The free air inlet from the claw valve in off position to the long milk tube should not be higher than 2 l min^{-1} (Bilgen & Oz, 2006; ISO5707, 2014; ISO6690, 2014).

The free air inlet in the claw is defined as the amount of air entering through the constant air inlet hole on the claw when the claw valve is in on position. Two methods for the measurement of the amount of air inlet in standards and researches are as follows (Bilgen & Oz, 2006; TS ISO 5707, 2014; TS ISO 6690, 2014). The first method is the measurement using rotameter, and the second is the measurement using bucket. According to the first method, the rotameter is connected to the milking claw with the long milk tube from its bottom end, and tothevacuumline with a second milk tube on the upper end. In the experiments, the teatcup liners of milking claws were removed and milk tubes each cut in 10 cm height were placed there. Air leaktightness was ensured by covering one side of milk tubes with silicone (Figs 2, 3). An operation vacuum was formed in the system by operating the vacuum pump, and the claw valve was opened. Meanwhile, the amount of air passing through the rotameter was observed. This value was recorded as '*the total amount of air leakage (l min^{-1})*' entering the claw. Then the value read in the rotameter by closing the free air inlethole on the milking claw was recorded as '*the claw valve leakage amount (l min^{-1})*'. The difference between the two measurements gave '*the amount of air leakage entering the free air hole (l min^{-1})*'.The pulsation was deactivated when applying these measurements.For this, long binary pulse tubes connected to the milking claw were removed. There are no free air inletholes on eight milking claws ('B', 'C', 'E', 'F', 'I', 'J', 'L' and 'O' type claws) within the scope of the research.

The second method is the measurement made using the milk bucket. According to this method, stainless steel milk bucket with a volume of 20 l with air leaktightness was used. The cover of the milk bucket is again made of stainless steel, and it has three milk–air output tubes. One of the output tubes was connected to the vacuum line with the long milk tube. A ball valve was placed on vacuum line connection. And the connection was made to the milking claw with a second milk tube. The third output tube on the bucket cover was additionally connected to the vacuum meter with an air tube (Fig. 3). After achieving the system operation vacuum pressure in the system, the ball valve was closed, and the chronometer was operated at the same time. The period that passes for the vacuum reduction of 10 kPa was detected. The time that passes for the vacuum change of 10 kPa was measured according to the following parameters:

1. The total amount of air leakage entering the claw (milk inlets are in off, and free air inlethole and claw vacuum closing valve are in on position),

2. The amount of air leakage entering the claw valve (milk inlets and free air inlethole are in off, and the claw vacuum closing valve is in on position),

3. The amount of air leakage entering the free air hole (found using the difference between the first and second measurements).

The following equation was used in order to calculate the amount of air leakage in the claw by the time measurements obtained (Bilgen & Oz, 2006):

$$q = \frac{6V}{T} \quad (1)$$

where: q – air leakage amount in the claw, l min^{-1}; V – Bucket volume, l; T – the time, that passes for a vacuum decrease of 10 kPa, s.

The measurement parameters obtained from rotameter and bucket methods were applied in three repetitions for each milking claw.

Figure 2. Experimental look made with the rotameter.

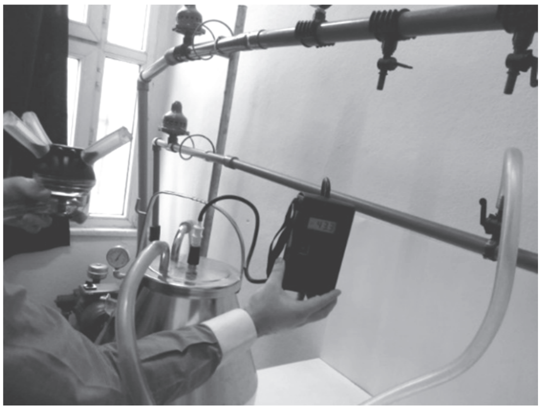

Figure 3. Experimental look made with the milk bucket.

In the experiments conducted with rotameter and bucket, the total amount of free air flow that enters through the free air inlethole and claw valve by air leakage should not be over 12 l min^{-1}. On the other hand, the free air inlet in total should be at least 4 l min^{-1} at nominal vacuum pressure. Otherwise, when the vacuum closing valve of the milking claw is off position, the free air flow into the long milk tube should not be higher than 2 l min^{-1} (Akam et al., 1990; ASAE Standards, 1998; Bilgen & Oz, 2006; TS ISO 5707, 2014; TS ISO 6690, 2014).

RESULTS AND DISCUSSION

Physical measurement results of milking claws

The measurement results regarding the capacities (internal volumes), weights and internal diameters of milk and pulse tubes of milking claws are given in Table 1. Examining the capacities of milking claws in Table 1, it has been determined that the milking claw of 'L' type has the lowest capacity of 70 ml and the milking claw of 'P' type has the highest capacity of 475 ml. With its volume, the milking claw of 'L' type has been found to be fewer than 80 ml, which is the minimum recommended capacity in the literature (Akam et al., 1990). On the other hand, in another study, it is suggested that the volume of a claw should be at least 150 ml (Dairynz, 2015). According to Dairynz (2015), it has been stated that the capacity of a milking claw should be at least 150 ml in order to keep animal teat-end under stable vacuum, prevent cross-flow in the claw and, contamination and liner slip between quarter milk entries in the claw. In accordance with the quantity stated, the milking claw of 'J' type has been identified to have a volume, which is close to this limit. All of the claws, except the claw of 'L' type, have provided the minimum amount required.

When the weights of the milking claws were measured, it was determined that 'H' type claw has the lowest weight with 237 g, and 'P' type claw has the highest weight with 729 g (Table 1). Although no weight limit is specified in TS ISO 5707 (2014) and TS ISO 6690 (2014) standards for the weight of the milking claw alone, it was reported by Akam et al. (1990) that the milking claws should be at least 0.5 kg and the milking cluster should be approximately 2.5 kg. In another study, it was reported that the weights of milking cluster as a whole may vary between 1.6 and 3.5 kg (Dairynz, 2015). According to Dairynz (2015), it was reported that commercial milking cluster in New Zealand is frequently between 2.2 and 2.6 kg. The weights of type 'C', 'D', 'E', 'H' and 'Q' milking claws within the scope of this research were found fewer than 0.5 kg, which is supposed to be, and the other claws are above this amount. And in the milking cluster weight measurements, it was found that the milking claw of 'H' type has the lowest weight with 1,730 g, and 'P' type claw has the highest weight with 2241 g. As it is seen in Table 1, 'C', 'D', 'E', 'H' and 'Q' type milking claws remained below 2 kg. Although these weights are within the limits of 1.6 and 3.5 kg specified in Dairynz (2015), all milking claws other than 'P' type milking claw were found fewer than the 2.2–2.6 kg values given in New Zealand example of the same literature. Furthermore, the weight of approximately 2.5 kg reported by Akam et al. (1990) was not ensured by any milking cluster within the scope of this research. The weight of the milking cluster is important, and the requested weight is directly related to the design of teatcup liner and milking claw. A too light milking cluster may lead to incomplete milking as it will create pressure on the teat-end of the animal, and too heavy milking cluster may lead to the fall off from the teat-end of the animal during milking (Akam et al., 1990).

Table 1. Some physical properties of eighteen different types of milking claws used in the research

Claw type	Claw volume, ml	Claw weight, g	Milking cluster weight, g	Short milk tube internal diameter, mm	Main milk tube internal diameter, mm	Pulse tube internal diameter, mm
A	225	531	2,081	10.8	15.7	8.0
B	170	578	2,090	7.7	12.6	6.9
C	175	404	1,916	7.0	12.7	8.4
D	170	478	1,976	7.5	13.6	5.7
E	185	423	1,935	8.8	13.1	5.7
F	320	514	2,000	7.9	15.7	6.3
G	235	564	2,076	8.6	16.3	7.4
H	180	237	1,731	5.5	13.0	5.5
I	185	551	2,162	7.4	13.7	6.3
J	155	507	2,019	7.5	13.5	6.5
K	215	588	2,100	7.7	13.9	7.6
L	70	531	2,106	7.3	11.9	5.5
M	350	556	2,068	8.4	15.9	7.6
N	240	554	2,066	8.4	14.0	7.9
O	160	582	2,094	7.6	13.3	6.9
P	475	729	2,241	5.5	13.5	5.5
Q	250	447	1,959	7.5	16.0	8.0
R	240	550	2,088	7.8	16.5	7.8

The minimum measures for the internal diameters of short milk, main milk, short pulse and long pulse tubes are specified in standards and different sources (Akam et al., 1990; TS ISO 5707, 2014). Accordingly, it is required that the internal diameter of short pulse tube should not be lower than 6 mm (5 mm according to Akam et al., 1990), and the internal diameter of the long pulse tube should not be lower than 6 mm in bucket milking machines and 7 mm in pipeline milking systems. Starting from the principle that the internal diameter values specified should also be the same in milking claws, the assessments were made in accordance with this principle.

The internal diameters of the short milk tubes of only five milking claws ('A', 'E', 'G', 'M', and 'N' type claws) fit the rule of being at least 8 mm. The internal diameters of the short milk tubes in these claws vary between 8.4 and 10.8 mm. The internal diameters of short milk tubes in 'H' and 'P' type claws were found to have quite a low value of 5.5 mm. The other eleven milking claws remained below the value indicated in the literature with the internal diameter values between 7.0 and 7.9 mm (Table 1).

The main milk tube internal diameter measures of the claws were found to be between 11.9 and 16.5 mm (Table 1). As it is seen in the Table, the internal diameters of all the claws except for the 'L' type claw were measured below the minimum limit of 12.5 mm that is requested.

The short pulse and long pulse tube of all claws in our study were made of the same measures. Thus, the assessments were made in accordance with the common values. The internal diameters of the pulse tubes of the claws were detected to be between 5.5 and

8.0 mm (Table 1). As it is seen in the Table, the pulse tube internal diameters of type 'D', 'E', 'H', 'L', and 'P' milking claws were found below the internal diameter value of minimum 6 mm specified in the standards (TS ISO 5707, 2014). On the other hand, it was determined that the short pulse tube diameter of the claws is above the limit of 5 mm, which is reported by Akam et al. (1990).

Rotameter measurement results

Claw closing valve leakage amounts

Claw valve leaktightness results measured with rotameter are shown in Fig. 4. As it is seen in the figure, air leakage between 0.0 and 2.0 l min^{-1} was measured in the on position of the milk inlets in the claw and off position of the vacuum plug in twelve milking claws ('A', 'C', 'E', 'F', 'H', 'I', 'J', 'K', 'L', 'N', 'P', and 'R' type claws). According to the principle of '*the free air entry from the claw valve in off position to the long milk tube side should not be higher than 2 l min^{-1} value*' reported by Bilgen & Oz (2006), claw valve leakage above the permissible limit occurred in six milking claws ('B', 'D', 'G', 'M', 'O' and 'Q' type claws). The amount of air leakage measured in the vacuum closing valve of these valves was found between 2.3 and 11.0 l min^{-1}.

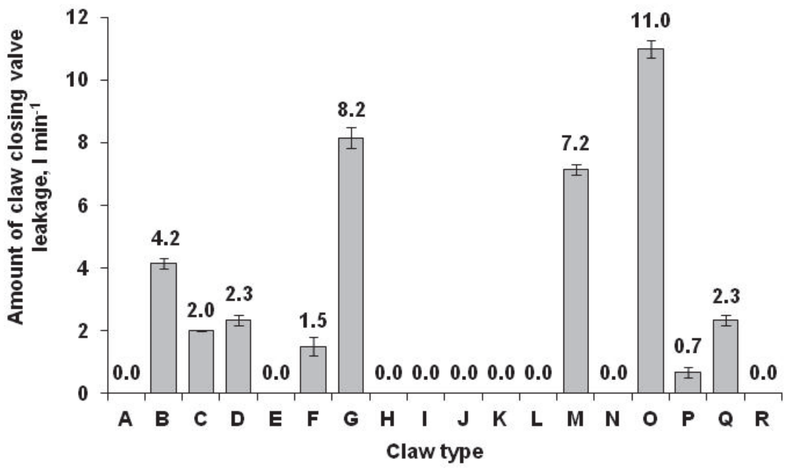

Figure 4. Amount of claw closing valve leakage measured with rotameter in different types of milking claws (claw milk inlets are open, and claw vacuum closing valve is in off position).

Total amount of air leakage entering the claw

The total amount of air leakage measured in the rotameter when claw milk inlets are in off and the claw valve and free air inlethole are in on position is shown in Fig. 5. As it is seen in the figure, it was determined that there is air leakage above 12 l min^{-1}, which is the maximum limit in three claws ('B', 'C', and 'H' type claws). On the other hand, 'F', 'G', and 'N' type milking claws were also found lower than the lower limit (4 l min^{-1}) withthe values between 1.8 and 3.8 l min^{-1}. The other twelve milking claws gave air leakage between minimum and maximum limits.

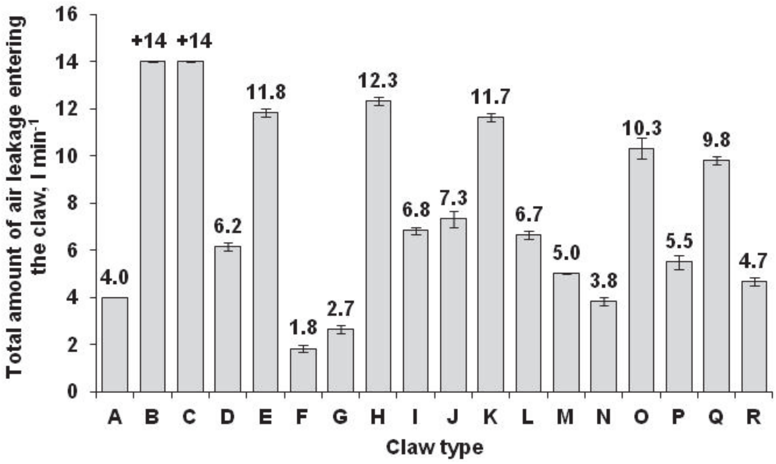

Figure 5. Total amount of air leakage entering the claw that is measured with rotameter in different types of milking claws (claw milk inlets are in off, and free air inlethole and claw valve are in on position).

Claw leakage amounts when the free air hole of the claw is in off, and the claw valve is in on position

Claw valve leakage amounts measured from the rotameter when claw milk inlets and free air inletholes are in off and the claw valve is in on position are shown in Fig. 6. As it is seen in the figure, the values measured from two claws ('B' and 'C' type claws) rose to 14 l min^{-1}, which is the maximum measurement limit of the rotameter. It was seen that the leakage amount of these two claws highly exceeded the upper limit of 12 l min^{-1} that is required.

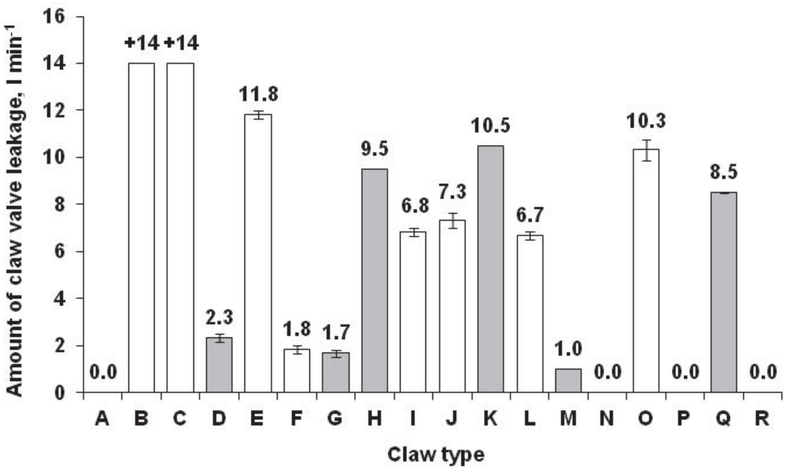

Figure 6. Amount of claw valve leakage measured with the rotameter in different types of milking claws (claw milk inlets and free air inlet hole are in off, and the claw valve is in on position).

Furthermore, the minimum air leakage amount that must be given by eight milking claws ('A', 'D', 'F', 'G', 'M', 'O', 'P', and 'R' type claws) was also found lower than the lower limit of 4 lmin^{-1}. Here, it is understood that in case ten free air inletholes mentioned above become congested or do not exist at all, the permissible amount of air leakage cannot be fulfilled. Thus, whether the claw free air holes are open should be checked before each milking. As it is explained in the method section, it was seen that eight milking claws ('B', 'C', 'E', 'F', 'I', 'J', 'L', and 'O' type claws) were produced without free air inlet hole. As it is seen in the figure, 'B', 'C', and 'F' type claws could not fulfill the minimum and maximum conditions.

Amounts of air leakage entering the claw free air inlethole

The amount of free air leakage allowed by ten different types of milking claws with claw free air inletholes is shown in Fig. 7. As it is seen in the figure, the amount of air passing through the free air hole of ten claws varies between 1.0 and 5.5 l min^{-1}. These values are the difference of the values in Figs 5, 6. The amount of air that constantly passes through the free air hole is important as it affects the minimum and maximumamount of air that must pass through the claw in total. When the figure is examined, only four ('A', 'M', 'P', and 'R' type claws) among ten claws allowed the leakage above the minimum limit. The amount of air passing through the free air holes of these claws was found between 4.0 and 5.5 l min^{-1}. The amount of air leakage of the remaining six claws was found to be lower than 4 l min^{-1}, which is the lower limit. These claws failed to fulfill the minimum amount of free air.

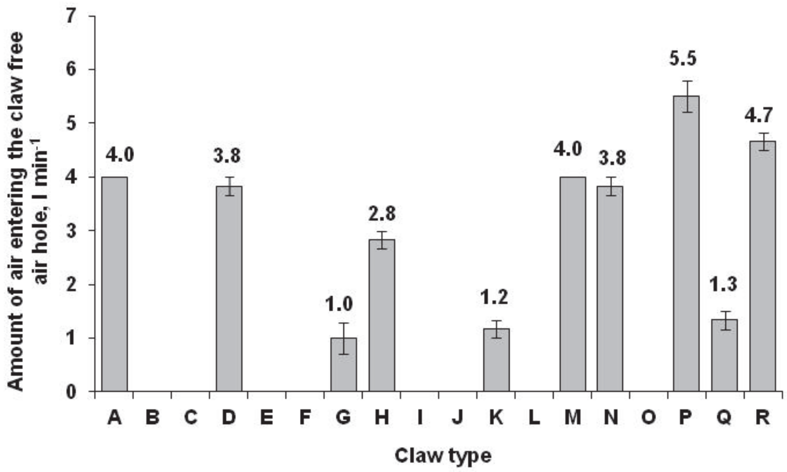

Figure 7. Amount of air entering the claw free air hole measured with rotameter in different types of milking claws (claw milk inlets and free air inlethole are in off, and the claw valve is in on position).

Bucketmeasurement results

A study was carried out with milk bucket as an alternative to claw air leakage measurements performed with a rotameter. According to the parameters given in the method section, the period measured for a vacuum change of 10 kPa in a bucket with a volume of 20 l is shown in Table 2. As it is seen in the table, the least duration for a vacuum change of 10 kPa in the 1st measurement parameter was measured (3.54 s) in 'K' type claw, while the longest duration was measured (29.50 s) in 'G' type claw. On the other hand, the shortest duration for a vacuum change of 10 kPa in the second measurement parameter was again measured (4.21 s) in 'K' type claw, while the longest duration was measured (70.11 s) in 'Q' type claw. The first and second measurement periods obtained from milking claws were put in their place in Equation [1] and given in Figs 8–10 by converting them to the amount of air leakage.

Table 2. The duration that passes for 10 kPa vacuum change according to the bucket experiment

Claw type	Measurement parameters	
	Time of first parameter[1], s	Time of second parameter[2], s
A	10.50 ± 0.40	20.29 ± 1.48
B	5.77 ± 0.36	~[3]
C	7.38 ± 0.33	~
D	9.12 ± 0.36	15.38 ± 0.63
E	7.93 ± 0.43	~
F	23.11 ± 1.29	~
G	29.50 ± 0.97	39.26 ± 1.54
H	5.85 ± 0.24	7.00 ± 0.21
I	14.13 ± 1.05	~
J	8.01 ± 0.56	~
K	3.54 ± 0.05	4.21 ± 0.25
L	22.56 ± 0.59	~
M	11.25 ± 0.19	22.37 ± 0.42
N	20.14 ± 2.02	65.61 ± 2.86
O	7.32 ± 0.17	~
P	25.77 ± 1.85	47.94 ± 7.30
Q	15.21 ± 0.54	70.11 ± 0.69
R	11.32 ± 0.50	19.32 ± 0.24

[1]First parameter: Claw milk inlets are in off, and the free air inlethole and claw valve are in on position; [2]Second parameter: Claw milk inlets and free air inlethole are in off, and claw valve is in on position; [3]No free air inlet hole; ± Standard deviation.

Total amount of air leakage entering through the claw

The total amount of air leakage passing through the claw for a vacuum change of 10 kPa when claw milk inlets were in off and the free air inlethole and claw valve were in on position in bucket experiment is shown in Fig. 8. As it is seen in the figure, the total amount of air leakage entering eight claws ('B', 'C', 'D', 'E', 'H', 'J', 'K', and 'O' type claws) exceeded the maximum limit value (12 l min^{-1}). Nevertheless, the total amount of air that should pass through all claws as a minimum was determined above 4 l min^{-1} that is provided for the lower limit. Here, it was concluded that eight claws gave leakage above the upper limit although the minimum amount of air that should pass through all claws is sufficient.

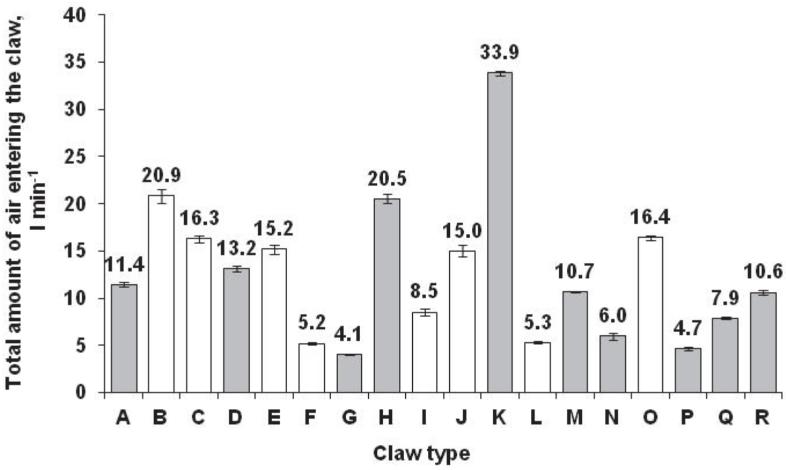

Figure 8. Total amount of air entering the claw that is measured with bucket in different types of milking claws (claw milk inlets are in off, and free air inlethole and claw valve are in on position).

Amount of claw leakage when the claw free air hole and claw valve are in on position

Claw valve leakage amounts calculated from bucket measurement when the milking claw is on and free air inlethole is in off position are shown in Fig. 9. As it is seen in the figure, data obtained from seven claws ('B', 'C', 'E', 'H', 'J', 'K', and 'O' type claws) exceeded the maximum air limit (12 l min^{-1}). On the other hand, four claws ('G', 'N', 'P', and 'Q' type claws) gave leakage below the minimum limit that must be with values between 1.7 and 3.1 l min^{-1}. As it is seen in the figure, five of eight different milking claws ('B', 'C', 'E', 'J' and 'O' type claws) with no free air inlethole (claws with white columns) gave leakage above 12 l min^{-1}.

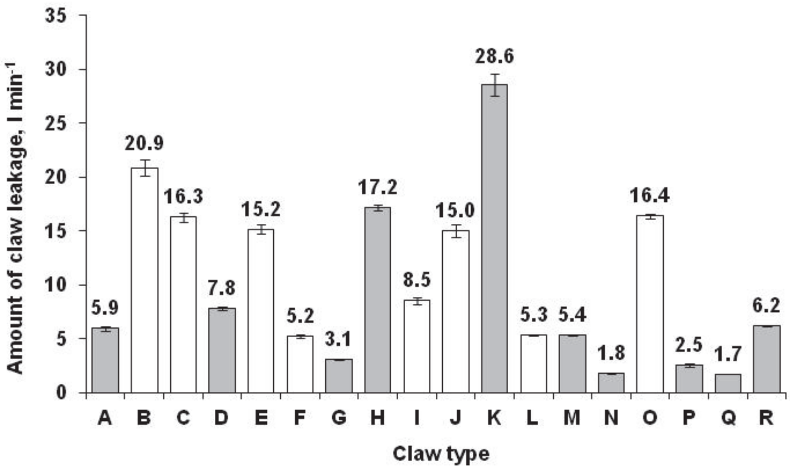

Figure 9. Amount of claw leakage measured with bucket in different types of milking claws (claw milk inlets and free air inlethole are in off, and the claw valve is in on position).

Amount of air leakage entering the free air hole of the claw

The amount of free air leakage allowed by ten different types of milking claws with free air inletholes is shown in Fig. 10. As it is seen in the figure, the amount of air passing through the claws with free air holes varies between 1.0 and 6.2 l min^{-1}. These values are the difference of the values calculated in Figs 8, 9. As it is also specified in the sectionof measurement with rotameter, the minimum and maximum limits of the amount of air that must pass through the free air inlethole are not specified in standards and other studies. However, the amount of air passing through the free air hole is important as it affects the minimum and maximum amount of air that must pass through the claw in total. Upon examining Fig. 10, the amount passing through the free air hole of 'G', 'H' and 'P' claws was found in the values of 1.0, 3.4 and 2.1 l min^{-1}, respectively. These values were found to be lower than the total amount of minimum 4 l min^{-1} that should pass through the claw. Here, it was seen that 'G', 'H' and 'P' type claws did not fulfill the minimum amount of air.

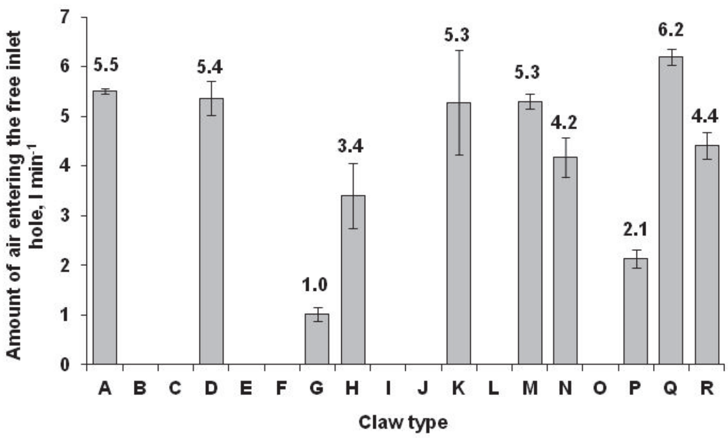

Figure 10. Amount of air entering the free air inlethole measured with bucket in different types of milking claws (claw milk inlets and free air inlethole are in off, and the claw valve is in on position).

CONCLUSIONS

Claw air leakage results are summarized below by the physical properties applied to eighteen different types of milking claws within the scope of the research, the methods of rotameter and bucket:

- Only the 'L' type claw among the milking claws was found below the minimum volume limit (80 ml) with 70 ml.
- It was determined that the weight of five of the milking claws ('C', 'D', 'E', 'H', and 'Q' type claws) was found below 0.5 kg, which is the minimum limit, and other claws are above this amount.
- The internal diameters of the short milk tube of only five of the claws ('A', 'E', 'G', 'M', and 'N' type claws) fulfilled the minimum 8 mm rule.

- The internal diameters of the pulse tube of 'D', 'E', 'H', 'L' and 'P' type claws were found below the internal diameter value of minimum 6 mm specified in the standards.
- In the claw valve leaktightness experiment carried out with rotameter, the claw closing valve leakage amounts of twelve claws were measured between 0.0 and 2.0lmin^{-1}, and it was determined that six claws exceeded the limit of 2.0 lmin^{-1}.
- In the experiments conducted usingrotameter, it was observed that the total amount of air leakage of six claws ('B', 'C', 'F', 'G', 'H', and 'N' type claws) remains outside the lower limit (4 l min^{-1}) and upper limit (12 l min^{-1}).
- According to the rotameter experiment, it was seen that only four of ten claws ('A', 'M', 'P', and 'R' type claws) with free air inletholes fulfilled the minimum amount of air leakage.
- In the experiments conductedwith the bucket, it was determined that the total amount of air leakage of eight of the milking claws ('B', 'C', 'D', 'E', 'H', 'J', 'K', and 'O' type claws) exceeds upper limit (12 l min^{-1}). On the other hand, it was determined that the minimum total amount of air leakage of all of the milking claws exceeds 4 l min^{-1}, which is provided for the lower limit.
- According to the bucket experiment, only three of ten claws ('G', 'H', and 'P' type claws) with free air inletholes have a minimum amount of air leakage below the lower limit of 4 l min^{-1}.

These results have shown that the quality and sensitivity required in the design and production of the milking claws used in bucket and pipeline milking machines has not yet been achieved.

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