J. Int. Environmental Application & Science, Vol. 4 (2): 136-145 (2009)

The Model Research on Constitution of Draught Free Area for Suitable Environmental Condition in Dairy Cattle Housing[#]

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Received December 27, 2008; Accepted April 15, 2009

Abstract: In this study, an alternative dairy building design was developed to keep environmental conditions optimum level for dairy cows. Adaptation to environment and constituting living area, without stress, close to natural sheltering region were aimed in this barn design. Free stall resting area has been constituted economically by designing feeding line out of closed area in free stall barn. Seasonal usage of areas for cows has been possible by constituting areas which can be used in summer and winter and has different features. Model analysis has been carried out by constituting a model of developed building. Stagnant area has been analyzed by testing the structure model in a wind tunnel. Air speed is measured within the model and in a real shelter. At the end of the studies, it was understood that, there is a significant similarity between real condition air speed values and air speed in the model. Air flow has been determined between 0.4-0.7 m/s, 0.8-1.0 m/s, and 1.0-1.2 m/s for 20 m, 24 m, and 32 m of lot width, respectively when wind speed was 3.5 m/s. Reduction of air flow in the direction of wind has been determined averaged 85 % for 20 m of yard width, 72 % for 24 m of lot width, and 66 % for 32 m of courtyard width.

***Key words**: Air flow, suitable environment for dairy cattle*

Introduction

In Turkey, the development of stock-breeding is important for the proper nutrition of increasing population. In proper nutrition, animal originated foods that include proteins and supply energy are as important as plant originated foods that are enriched by carbohydrate (Ugurlu & Uzal, 2008).

Reaching to high efficiency level by the animals is first of all related with the stress factors of the environment. The stress is resulted from various factors affecting on animals by slowing down their production function and production performance drop significantly. Stress affecting the animal can be originated from various factors. They are mainly climatic, structural and social factors. Climatic stress is the negative effect of climate on the environment where the animals live. Structural and social factors are directly related to barn planning and design. Also climatic conditions are affecting the planning and design of building, additional structures and facilities. Also the materials used in animal housing building and their conformity with the purpose affect the success of planning and design style (Ugurlu & Uzal, 2004).

Although the cow population is high in Turkey, the milk production level per cow is low. Reaching to the desired level in animal production can be achieved by developing genetic level with high quality as well as building barns that can fulfil the animal requirements.

However when the applications are checked, like many researchers' observations as in the other regions of Turkey, it is seen that shelter planning criteria are not taken into enough consideration (Ugurlu & Kara, 1994).

When selecting the housing system, barns that are suitable for animal behaviours and providing an environment with low stress level should be preferred. In building design, issues such as security, freedom of movement, keeping the feeding and movement areas away from wind in cold seasons,

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[#]*This paper is presented from Ph. D. Thesis of Selda Uzal* labour efficiency, letting the animals take advantage of clean air and sun, keeping the base dry should be taken into consideration (Ugurlu & Uzal, 2002).

In this study, alternative animal housing design with free station is developed which provides different area usage to animals in different seasons. In traditional system with free stall dairy housing, the feeding line is taken out of the closed area and an economic building with a small width is formed. In this recently developed design type, feeding is made in the middle yard within the draught free area which provides a more comfortable environment for animals in winter. For summer seasons, an outer open yard is formed in order to increase air speed. In the study, a scale model of the developed barn is made in order to supervise the success of placid yard concept and air speed values are measured in wind tunnel.

Materials and Method

In the study, conform increasing systems are considered and accordingly designs are made related with animal housing arrangement and development. In the designed barn type, closed resting sections are considered with free stall and feeding section is carried to the yard to decrease building width and accordingly cost. In this design type, the middle yard that will include feeding section in winter will increase the animal comfort in winter and accordingly strengthen the placid area concept. Especially regarding wind speed which has a negative effect on animals are reduced in areas where animals move freely, placid yard system design in means of air flow is made and the suitable dimensions of this area are tried to determine.

Developed barn view plan is given in Figure 1. Some changes are made in the project shown in figure 1 and is selected as prototype, then a 1/30 scale model is made that will represent the prototype. In studies made by Froehlich *et al*. (1975) with 1/6 scale model and in studies made by Yaganoğlu (1988) with 1/20 scale model cow shelter, they state that the roof ridge opening type is very important in measuring ridge air flow rate. In the determination of the model scale, applicability of measurements and observations, lab facilities and portability is taken into consideration. The barn model is made of mica and dimensions are changeable. The cross section and perspective view is shown in figure 2. Trials are conducted with 2 different roof slopes (26° and 36°), 3 different side wall heights (3.60, 4.50, 5.40 m) and 3 different yard widths (20 m, 24 m, 32 m).

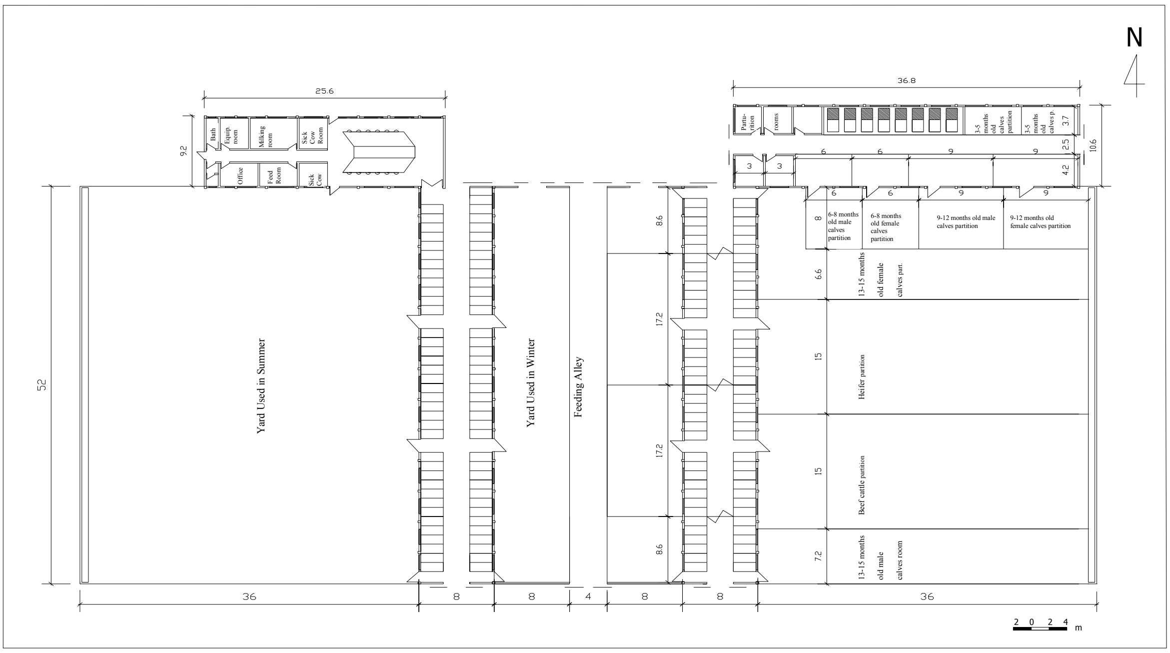


Figure 1. The view plan of designed animal housing in study

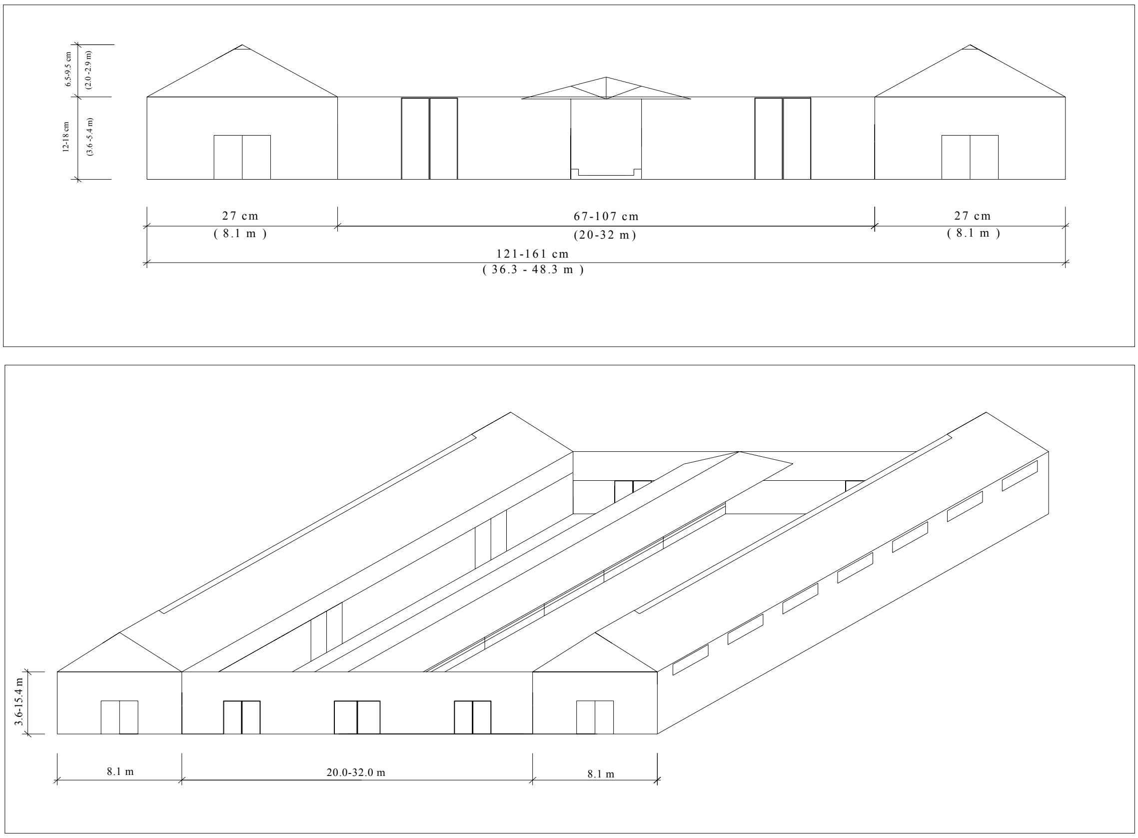


Figure 2. The prepared model barn perspective and cross section view (scale: 1/30)

In the study, a wind tunnel was formed in order to obtain the artificial wind in lab conditions. The studies by Bozdogan and Bayat (2003) and Yaganoglu (1988) are used of wind tunnel. The dimensions of the wind tunnel are given in figure 3. Digital air speedometer is used to determine the air speed in the model and wind tunnel (measurement range 0-15 m/s, resolution 0.1 m/s) In order to determine the direction and distribution of the air flow, smoke and Styrofoam pieces which give accurate response to air movement are used.

In this study, a different approach is considered and barn systems with free stall in various economical types, which provide a more suitable living area for animals, are designed. The 1/30 scale model of this system is made by mica. The model is designed for testing air speed, which is the most important factor for creating a climate within the shelter. Artificial air flows are created in the wind tunnel and trials are made. The measurement points of air speed in barn view plan and cross section (model) are shown in Figure 4. The air flow speed measurement was made at animal levels about 2 m in model barn.

It is determined whether the studies made on model in the lab reflect the real conditions or not. In order to determine whether the data obtained from the model is reflecting the real values or not, or in order to test the reliability of the data, measurements are also made on a real shelter at the same time. For this purpose, two digital devices showing the wind speed and direction are placed in the outer part of the barn and within the yard. (Measurement range 0-44 m/s, resolution 0.19 m/s, direction: 0-358º, resolution: 1.4º) wind speeds and directions are measured for 9 days with 5 seconds intervals. Air speed is measured within the model and in a real shelter. At the end of the studies, it was understood that, there is a significant similarity between real condition air speed values and air speed in the model.

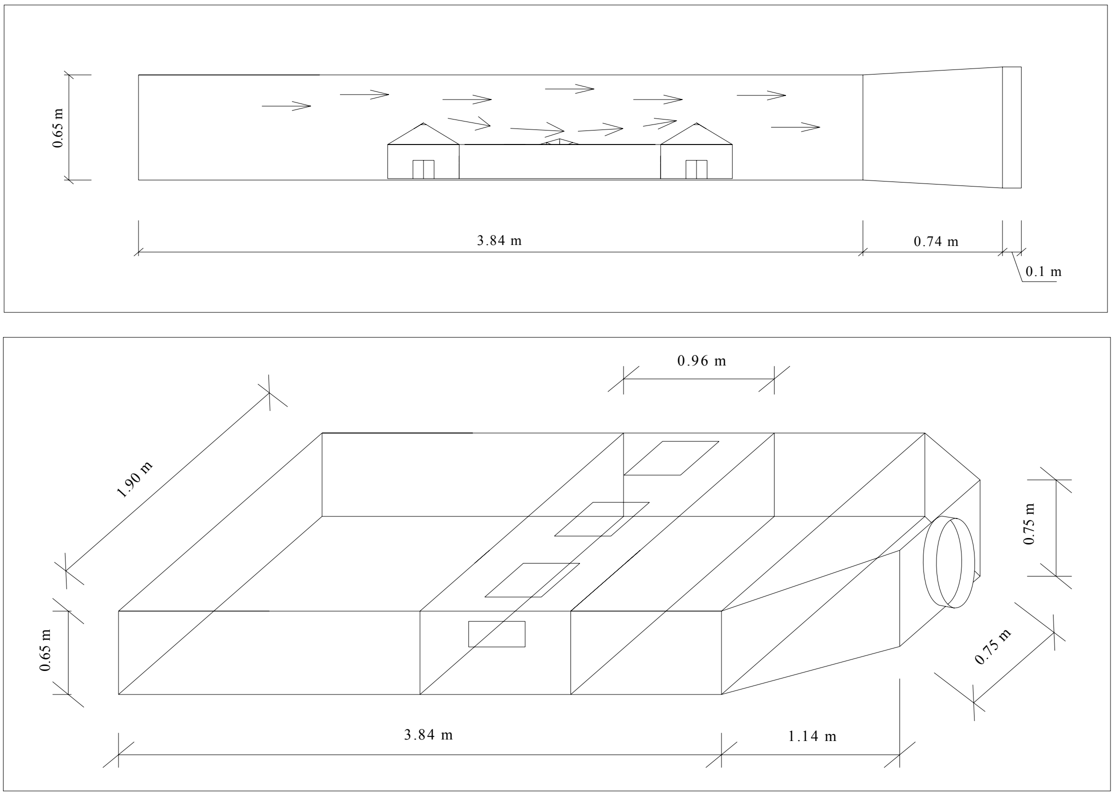
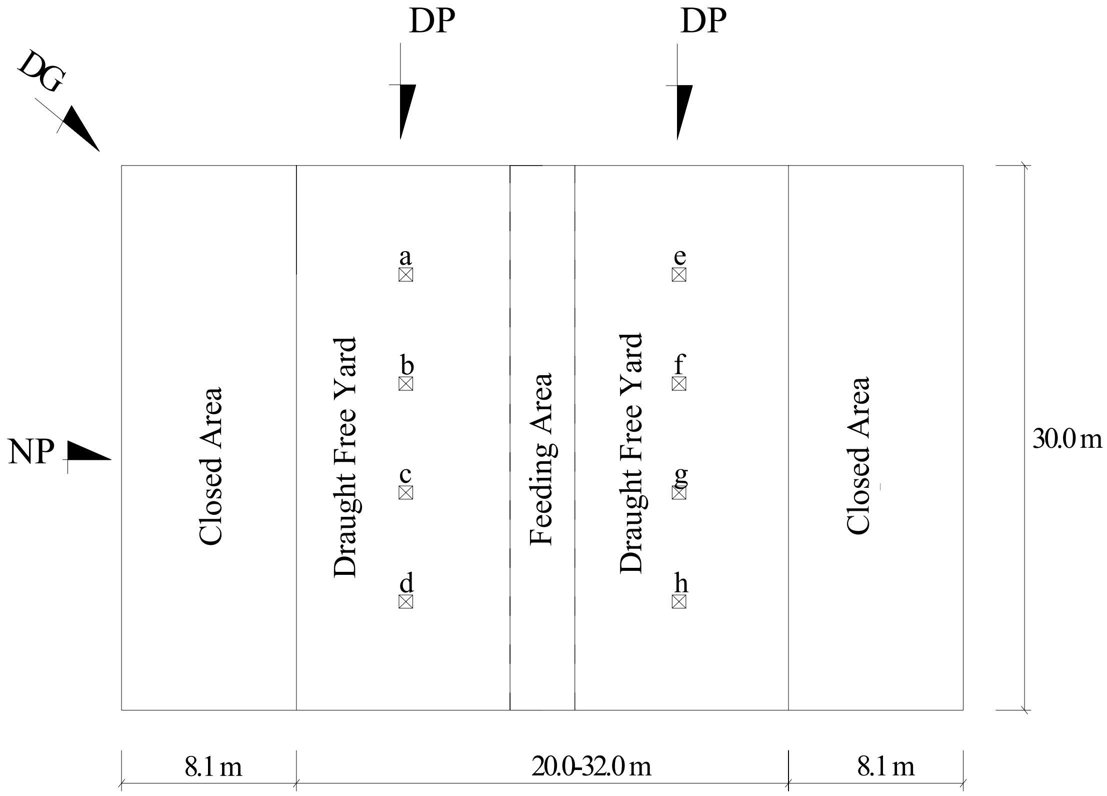


Figure 3. The perspective and cross section view of wind tunnel



*NP: Normal Position, DG: Diagonal, DP: Direct Position.
a,b,c,d,e,f,g,h: measuring points

Figure 4. The air flow speed measured points and wind hitting location of building

Results and Discussion

Comparing the Real Barn and Model Conditions

In the study, the air speed values in the model and real shelter are measured. There is a significant relation between the values. The relation between barn and model values in wind speed of 3.5 m/s is shown in figure 5.As seen in figure 5, there is a significant relation between real values and model values. The correlation coefficient between real barn and model in same speed conditions is R=0.9768. Considering that this coefficient varies between -1 and +1, the significance of the relation will be better understood. According to the data, it is highly possible that values in the model are reflecting the real values.

Due to the significant relation between model and real barn values, many studies that are hard and expensive to conduct in field conditions will be made easily in lab conditions and more economically.

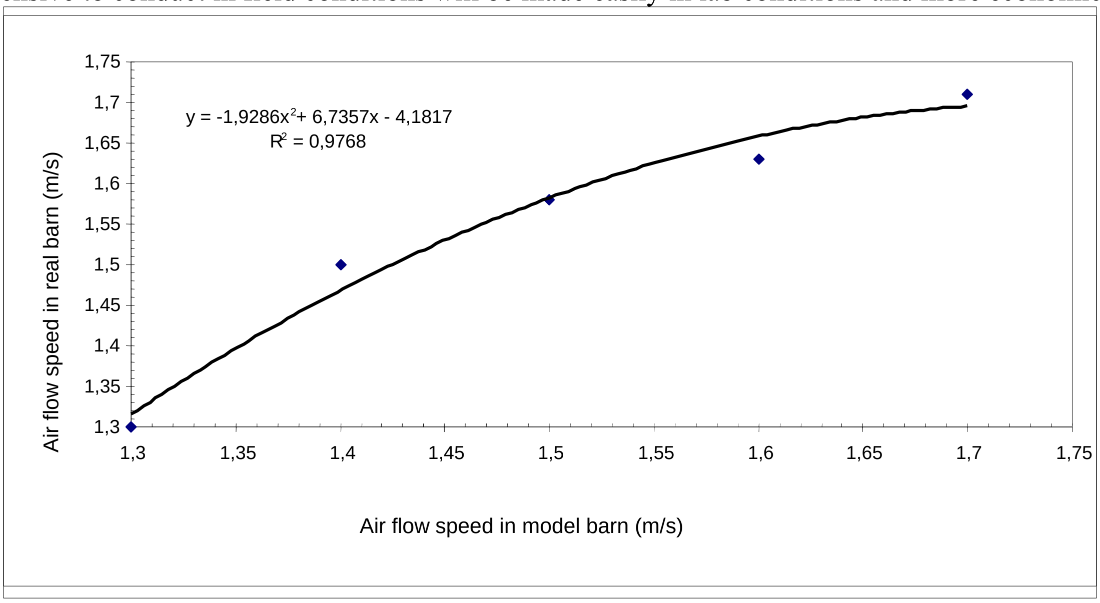


Figure 5. The air flow speed relation between real and model barn for wind hitting to building at 3.5 m/ s

General Air Speed Distributions and Directions in Model Housing

In the study, the general direction and distribution of air movement in animal housing model are determined. In figure 6, the directions and distributions of airflows in barn cross section and in figure 7, the distribution and direction of wind in the view plan of barn model, are shown. When the figures are observed, it is understood that wind gains speed and height with roof slope but after a certain distance it moves down to the housing floor due to the weight of air. It is understood that the airflow moving downwards causes a light wind in the yard floor. The yard width should be planned carefully in order not to let the airflow harm the animals. Together with this study, some dimensional values of barn design related with creating suitable climatic conditions within the building for animals are determined (Barn location, building side wall height, roof slope, yard width).

Measured Air Speed and Changes in Barn Model

In the study, within the wind tunnel formed in lab conditions, the effects of different wind speeds (3.5 m/s, 2.5 m/s, 1.5 m/s), different yard widths (20 m, 24 m, 32 m) and different shelter side wall heights (3.6 m, 4.5 m, 5.4 m) on the air speed formed within the yard are examined. In table 1, the air speed and changes at a wind speed of 3.5 m/s are given.

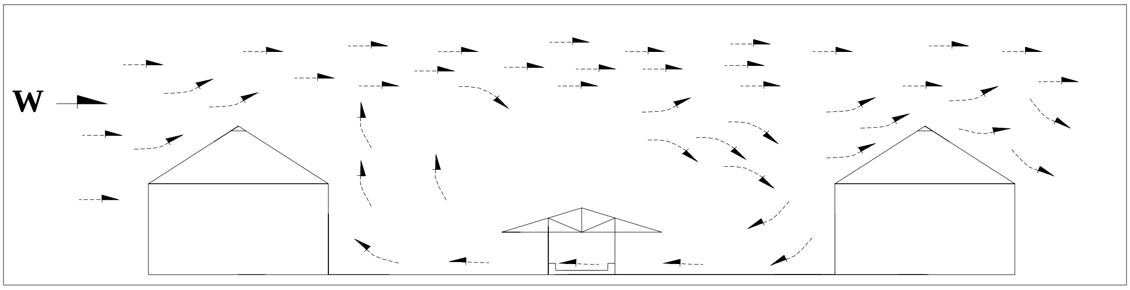


Figure 6. The air flow direction and distribution in cross section of barn

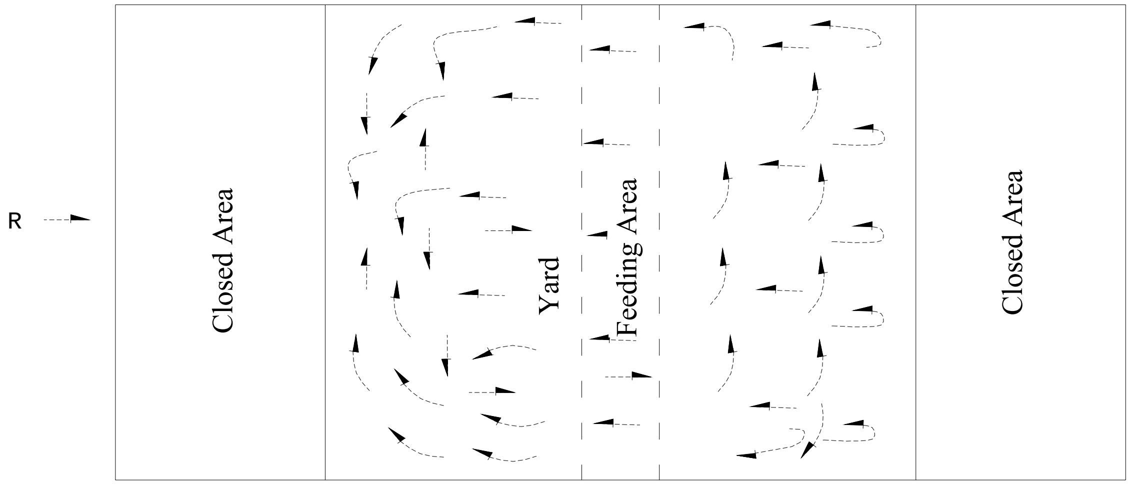


Figure 7. Formation of air flow direction and distribution in yard

Table 1. The measured air flow speed in draught free yard system for different yard width, sidewall height and roof slope (wind hitting 3.5 m/s to building)

Yard width (m)	Sidewall height (m)	Roof slope (°)	Air flow speed in different points of draught free yard system (m / s)											
			a	b	c	d	mean	Reduction (%)	e	f	g	h	mean	Reduction (%)
20	5.4	36	0.4	0.3	0.4	0.4	0.4	*88.6*	0.6	0.3	0.5	0.5	0.5	*85.7*
		26	0.5	0.5	0.4	0.5	0.5	*85.7*	0.6	0.6	0.7	0.7	0.7	*80.0*
	4.5	36	0.4	0.3	0.2	0.4	0.3	*91.4*	1.0	0.9	0.8	0.8	0.9	*74.3*
		26	0.5	0.4	0.8	0.7	0.6	*82.9*	0.9	0.6	1.0	0.8	0.8	*77.1*
	3.6	36	0.7	0.7	0.6	0.6	0.7	*80.0*	0.9	1.0	0.8	0.9	0.9	*74.3*
		26	0.7	0.6	0.8	0.8	0.7	*80.0*	0.7	0.6	0.6	0.8	0.7	*80.0*
24	5.4	36	0.9	0.9	0.7	0.8	0.8	*77.1*	1.2	1.3	1.0	0.9	1.1	*68.6*
		26	0.9	0.9	1.0	1.2	1.0	*71.4*	1.2	1.4	1.5	1.2	1.3	*62.9*
	4.5	36	0.9	0.8	0.9	0.9	0.9	*74.3*	1.2	1.1	1.3	1.2	1.2	*65.7*
		26	1.0	0.9	0.9	1.0	1.0	*71.4*	0.8	0.9	1.2	1.5	1.1	*68.6*
	3.6	36	1.0	1.0	0.9	0.9	1.0	*71.4*	1.2	1.3	1.3	1.2	1.3	*62.9*
		26	1.0	1.0	1.0	1.2	1.1	*68.6*	1.4	1.3	1.4	1.3	1.4	*60.0*
32	5.4	36	0.9	0.9	1.0	1.0	1.0	*71.4*	1.5	1.4	1.5	1.6	1.5	*57.1*
		26	0.9	1.2	1.4	1.2	1.2	*65.7*	1.5	1.4	1.6	1.5	1.5	*57.1*
	4.5	36	1.1	1.0	1.2	1.3	1.2	*65.7*	1.5	1.4	1.6	1.5	1.5	*57.1*

As seen in Table 1, in the designed draught free yard system, significant decreases are obtained in air speed. When the yard width is 20 m, the air speed decreased from 3.5 m/s to 0.3- 0.4 m/s. In Generally, there is 88-91% decrease in the air speed formed in the front yard (where the wind blows from) In the back yard, (where the wind leaves) the air speeds are decreased down to 0.5-0.7 m/s for a yard width of 20 m. The decrease percentage in air speed is 80 – 85%. In this designed system, the feeding block and the placid yard located at both sides are separated in to 2 symmetric sections. These sections become front or back yards according to the direction of the wind. Because of the distance, air speed in the back yard is a little bit higher than in the front yard. The wind, which slows down when there is a windbreak, gains speed with increasing distance. When figure 6 and table 1 is examined, the air hitting to the structure, which serves as a windbreak, gains acceleration with the roof slope but after a certain distance it starts to make free fall and descend. It is seen in figure 6 that, the descending air approaches to the yard floor and hits the opposite wall, thus creating a circulation in the yard.

In this study, it is seen that, the yard width is the most important factor in draught free area formation (Figure 8). For example, in the wall height of 5.4 m and a roof slope of 36 º, the speed values measure in front yard in 20, 24 and 32 m yard widths, are 0.4 m/s, 0.8 m/s and 1.0 m/s respectively. Generally, distance is very important in strengthening the placid area concept while the effects of wall height and roof slope are not much. The air speed being under 1 m/s in a yard width of 20 m, will contribute to climatic animal comfort in winter season. When the yard width was increased to 32 m, the placid area formation weakened due to increasing distance so all measurements could not be made.

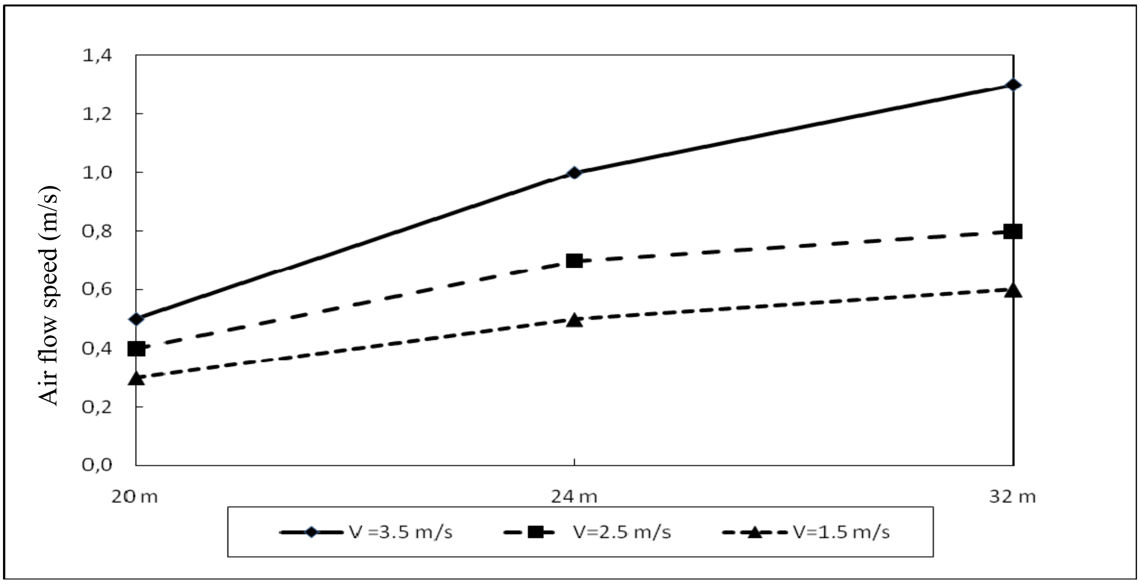


Figure 8. The effects of yard width on decreasing of air flow speed (sidewall height 5.5 m and roof slope 36 ^{0})

In free and open shelter systems, air speed is the most important factor in arranging the climate conditions within the shelter. In cold seasons, high air speed increases the heat lost from the animal by convection thus decreases the temperature that is felt by the animal. The air speed values that will not have a negative effect in cold seasons are suggested to be 0.2 – 0.3 m/s by Mutaf and Sonmez (1984) and 0.4 m/s by Charles (1994). Sainsbury and Sainsbury (1988) state that air speed over 2 m/s are considered as harmful air flow while they assume the 0.2 m/s air speed, as placid environment. Charles (1994) gives the critical low temperature as +17 ^{O}C when air speed is 4 m/s and barn floor is wet (50% of the animal body surface is wet), while the critical low temperature is -9^{O}C in draught free weather and dry floor conditions. As the high air speed increase the heat loss by convection in winter season also increases. Besides, if a part of the body is wet, the animal is forced to emission latent heat. These factors increase the total heat loss and the real felt temperature by the animal decreases a lot. Temperature, which is one of the most important climatic parameters, does not have much meaning by itself. As stated by the researcher above, the tolerance shown by the animal in one condition at -9 ^oC, is the same as the tolerance shown by the animal in +17 ^oC. Accordingly air sped is a factor that should be taken into consideration for determining the animal performance in cold seasons. In open and free shelter systems, the studies for strengthening the draught free areas against the high air speed, which is the most important production and efficiency problem, are quite essential. Keeping the animals away from the stress of cold during winter season, will improve their efficiency.

In this study, the building design related to the formation of draught free yard type in open and free shelter system is developed, the air speed formed in the designed placid yard system is measured and accordingly the success of the system is shown.

When the wind speed is 2.5 m/s the air speed values in the yard are measured as 0.3 - 0.6 m/s, 0.5 - 1.0 m/s and 0.6 - 1.3 m/s for the yard width values of 20 m, 24 m and 32 m respectively. The air speed decrease in percentage in the direction where the wind is coming is 84%, 76% and 75% for yard widths of 20m, 24m and 32m respectively. When the air speed values given in the table 2 are examined, it is seen that all sidewall height values for yard width values of 20 m and 24 m are suitable for cows. When the yard width is 32 m and sidewall height is 5.4m, the obtained air speed values are close to the desired values. It can be stated that a back yard width of 20 – 24 m for regions where the wind speed is around 2.5 m/s will be a good selection for successful planning (Table 2).

Table 2. The measured air flow speed in draught free yard system for different yard width, sidewall height and roof slope (wind hitting 2.5 m/s to building)

Yard width (m)	Sidewall height (m)	Roof Slope (^{o})	Air flow speed in different points of draught free yard system (m / s)											
			a	b	c	d	mean	Reduction (%)	e	f	g	h	mean	Reduction (%)
20	5.4	36	0.3	0.3	0.2	0.2	0.3	*88.0*	0.4	0.4	0.4	0.4	0.4	*84.0*
		26	0.3	0.4	0.3	0.5	0.4	*84.0*	0.6	0.5	0.6	0.4	0.5	*80.0*
	4.5	36	0.2	0.3	0.3	0.4	0.3	*88.0*	0.5	0.6	0.5	0.5	0.5	*80.0*
		26	0.3	0.3	0.5	0.4	0.4	*84.0*	0.4	0.5	0.4	0.3	0.4	*84.0*
	3.6	36	0.3	0.4	0.3	0.3	0.3	*88.0*	0.4	0.6	0.5	0.5	0.5	*80.0*
		26	0.4	0.5	0.4	0.5	0.5	*80.0*	0.5	0.5	0.6	0.6	0.6	*76.0*
24	5.4	36	0.7	0.6	0.5	0.5	0.6	*76.0*	0.7	0.8	0.8	0.7	0.8	*68.0*
		26	0.5	0.4	0.5	0.6	0.5	*80.0*	0.7	0.8	0.7	0.6	0.7	*72.0*
	4.5	36	0.5	0.4	0.4	0.5	0.5	*80.0*	0.7	0.9	0.9	0.8	0.8	*68.0*
		26	0.5	0.4	0.4	0.7	0.5	*80.0*	0.9	1.0	1.0	0.8	0.9	*64.0*
	3.6	36	0.6	0.6	0.5	0.4	0.5	*80.0*	0.8	0.9	1.0	0.9	0.9	*64.0*
		26	0.7	0.6	0.7	0.7	0.7	*72.0*	0.9	1.0	1.1	0.8	1.0	*60.0*
32	5.4	36	0.6	0.5	0.6	0.7	0.6	*76.0*	1.0	0.9	1.0	1.2	1.0	*60.0*
		26	0.7	0.6	0.7	0.6	0.7	*72.0*	1.2	1.2	1.3	1.3	1.3	*48.0*
	4.5	36	0.5	0.5	0.7	0.6	0.6	*76.0*	0.9	1.0	0.9	1.0	1.0	*60.0*

In placid yard systems, when the wind speed is 1.5 m/s, the air speed decrease in percentage in the direction where the wind is coming, is 86%, 75% and 67% for yard widths of 20 m, 24 m and 32 m respectively (Table 3). This is shown in table 3. When the table is examined, it is seen that all obtained air speed values, are desired values for cows. When the yard width is 32m and side wall height is 5.4m, the obtained air speed values are suitable to the desired values. According to the measurement values when wind speed is 1.5 m/s, it is considered that all speeds that will be obtained for shelter planning will be suitable for cows.

As a result, when the table 1, 2, 3 and Figure 8 is examined, it is seen that, in draught free yard design, the obtained air flow speed values are below the harmful airflow limit in many of the experimental subjects, while in some subjects, the obtained values are close to the desired values for animals.

Table 3. The measured air flow speed in draught free yard system for different yard width, sidewall height and roof slope (wind hitting 1.5 m/s to building)

Yard width (m)	Sidewall height (m)	Roof slope (°)	Air flow speed in different points of draught free yard system (m / s)											
			a	b	c	d	mean	Reduction (%)	e	f	g	h	mean	Reduction (%)
20	5.4	36	0.2	0.2	0.1	0.1	0.2	*86.7*	0.3	0.3	0.3	0.4	0.3	*80.0*
		26	0.2	0.2	0.1	0.2	0.2	*86.7*	0.3	0.3	0.4	0.3	0.3	*80.0*
	4.5	36	0.3	0.2	0.2	0.2	0.2	*86.7*	0.3	0.3	0.3	0.4	0.3	*80.0*
		26	0.2	0.2	0.2	0.2	0.2	*86.7*	0.4	0.4	0.5	0.3	0.4	*73.3*
	3.6	36	0.1	0.2	0.2	0.3	0.2	*86.7*	0.4	0.5	0.6	0.5	0.5	*66.7*
		26	0.2	0.2	0.3	0.3	0.3	*80.0*	0.3	0.3	0.3	0.2	0.3	*80.0*
24	5.4	36	0.5	0.4	0.4	0.4	0.4	*73.3*	0.4	0.6	0.6	0.5	0.5	*66.7*
		26	0.3	0.3	0.3	0.4	0.3	*80.0*	0.4	0.6	0.5	0.4	0.5	*66.7*
	3.6	36	0.3	0.4	0.4	0.3	0.4	*73.3*	0.7	0.6	0.8	0.7	0.7	*53.3*
32	5.4	36	0.5	0.5	0.5	0.4	0.5	*66.7*	0.7	0.7	0.6	0.5	0.6	*60.0*

Conclusion

In the study, the animal housing design that minimizes the climatic and structural stress for dairy cattle is conducted. The model of the designed animal building is prepared and is tested within the wind tunnel in order to examine the air speed and distribution. As a result, significant decreases in air flow speeds, which are the most important parameter that determines the climatic comfort in winter season, are obtained. In the formed draught free yard system, the air speed is decreased from 3.5 m/s to 0.4-0.5 m/s (80% - 90% decrease).

Acknowledgement: *This work was supported by Scientific Research Project Fund of Selcuk University (Project Number: 2003/131)*

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