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Production environment of beef cattle farms in relation to the incidence of DFD meat

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Abstract. In 1979–80, DFD (dark, firm, dry) meat was obtained from 26.3 % of the bulls slaughtered in Finland. The incidence of DFD meat depends closely on the mode of lairage at the slaughterhouse. In the present study, the frequency of DFD meat in 693 bulls reared at 45 farms was examined in relation to the production environment on the farms.

The incidence of DFD meat is increased by housing in group pens at the slaughterhouse, high atmospheric humidity and poor hygiene in the farm buildings, failure to keep the animals clean and rearing in standings. In an analysis of variance, 29.9 % of the variation in the pH of the carcasses was explained when the independent variables were: the mode of lairage at the slaughterhouse (group pens vs. individual spaces, 17.1 %), the atmospheric humidity in the farm buildings (8.6 %), the management at the farms (pens. vs. standings, 6.3 %), the slaugterhouse (three slaughterhouses 3.8 %) and the level of hygiene at the farm (1.9 %). The reduction in the variation explained caused by the removal of each variable is given in percentage units in parentheses.

The influence of feeding was slight, being smaller than that of a good rearing environment and individual spaces at the slaughterhouse, but intensive feeding and a high growth rate were also connected with a low DFD percentage.

Introduction

Great stress is caused in beef cattle before slaughter by their removal from the familiar environment and social relationships at their farms and by their transport to and stay at the slaughterhouse, especially the latter. This results in inadequate reserves of glycogen in the muscular tissues at the time of slaughter, inadequate gycolysis, and an insufficient decline in the pH of the meat. The muscle of these animals may become what is known as DFD (dark, firm, dry) meat.

A large-scale survey was carried out in Finland in 1979–80 on the occurrence of DFD meat, the factors responsible and the utilization of such beef (PUOLANNE et al. 1981). DFD meat occurred in 26.3 % of the bulls slaughtered in Finland, the frequency being highest in June–July and lowest in February. The incidence of DFD meat was strongly influenced by the management at the slaughterhouse. In animals kept in standings or individual pens, the frequency of DFD meat was 14 %, whereas in animals kept in group pens it was 34 %. Besides the management at the

slaughterhouse, other factors influencing the occurrence of DFD meat were the distance and duration of transport, the length of the holding period at the slaughterhouse and the size of the animal. Since these did not explain a sufficient fraction of the variation in the frequency of DFD meat, factors must also be sought in the rearing environment. However, the literature contains little information on this point and there are no investigations suiting the conditions in Finland.

The aim of this study was to elucidate the effects of management, production hygiene and feeding on the incidence of DFD meat in bulls.

Fifty-seven farms specialized in raising beef cattle were chosen in three areas of Finland served by three different slaughterhouses: Forssa, Savonlinna, Kauhajoki (F, S and K). Visits were made to the farms to collect data on the production environment, the feeding and management during the different rearing phases and the characteristics of the animals. During the large-scale study on DFD meat (PUOLANNE et al. 1981), cattle were sent for slaughter from 45 of the farms, and this material is included in the treatment of the results. The number of animals at the individual farms averaged 99.

Of the 759 animals sent to the slaughterhouses, 693 were bulls, 47 were heifers and 19 bullocks and cows. This study will be restricted to the bulls. Of these, 82 % were of the Ayrshire breed, 12 % were Friesians or crosses between Friesians and other dairy breeds, and 6 % were beef breeds (Charolais or Hereford) or crosses between these breeds and dairy cattle. The weight of the bulls at slaughter averaged 211±27 kg and their age at slaughter 14±1.5 months.

The pH value of *M. longissimus dorsi* was determined at the slaughterhouse 24 h post mortem, near the 5th–6th vertebra at a depth of 3 cm (Digital pH meter 651, Knick).

The visits to the farms were made in April–May and the slaughterhouse data were collected in April–May and August–September 1979.

Results

Incidence of DFD meat

The pH of *M. longissimus dorsi* averaged 5.67±0.28. Slightly DFD meat was found on 10.1 % of the bulls (pH = 6.00–6.39) and strongly DFD meat in 2.7 % (pH $\geq$ 6.40). The slaughterhouse areas differed greatly in the incidence of DFD meat: in area F the proportions of the 349 bulls yielding slightly or strongly DFD meat were 4.3 % and 1.1 %, respectively; in area S, with 130 bulls, they were 16.9 % and 1.5 %, and in area K, with 214 bulls, 15.4 % and 6.1 %.

In the animals kept in standings or individual pens before slaughter, the DFD percentage was 3.7 and in the animals kept in group pens it was 24.4. The percentages of animals kept in individual housing were as follows: slaughterhouse F 84 %, slaughterhouse S 39 % and slaughterhouse K 26 %.

In one in three of the farms, over 20 % of the carcasses had DFD meat: area F, 2 farms out of 15, area S 3 farms out of 12 and area K 10 farms out of 18.

Housing

The calves were delivered to the beef farms when they were 2–6 weeks old, being mainly procured through the slaughterhouse. The rearing time was divided

into the suckling period (4—7 weeks), the calf period (2—6 months) and the fattening period (6—14 months). The length of the suckling period and the density of the animals in the suckling department (average 1.0±3 m^2/calf) showed no correlation with the incidence of DFD meat.

The density of animals during the calf period (average 1.8±1.1 m^2/animal) had no correlation with the incidence of DFD meat. On the other hand, in the animals reared in separate calf departments (227 bulls) the DFD incidence was only 5.7 % and in the others (466 bulls) it was 17.3 % ($P < 0.001$). No difference was found in area K. In the calves reared indoors, the animals kept in pens ($n = 410$) had a DFD incidence of 11.5 % and those kept in standings ($n = 115$) had a value of 23.5 % ($P < 0.001$).

Among the animals held indoors during the fattening period, the DFD and the other bulls had the same amount of space in the pens (2.2 m^2) and standings (1.5 m^2). Among the animals reared outdoors, the DFD animals had an area of 4.7 m^2 and the others 6.4 m^2. The difference is not statistically significant.

The proportion of bulls held outdoors during the fattening period was 29 %: In area F it was 35 %, in area S 15 % and in area K 27 %. The incidence of DFD meat among the animals held outdoors was 7.5 % and among the animals held indoors it was 15 % ($P < 0.001$). The incidence in the different areas is shown in Table 1. In area K the management practice showed no correlation with the incidence of DFD meat.

Among the fattening animals kept indoors, those kept in pens (215) had a DFD incidence of 10.7 % and those kept in standings (278) had a value of 18.3 % ($P < 0.02$). The difference between the housing practices was great in areas F and S, but in area K it was in the opposite direction (Table 1).

Among the animals held in group pens at the slaugterhouse, the housing practice at the farm does not cause any statistically significant differences in the incidence of DFD meat (Table 2). In the animals kept in separate spaces at the slaughterhouse, the incidence of DFD meat differs significantly with the management at the farm.

Level of hygiene

The level of hygiene, estimated during the visits to the farms, showed a correlation with the incidence of DFD meat (Table 3).

The level of hygiene was highest in area F, 70 % of the carcasses originated from farms where the level of hygiene was considered to be good or even higher. The corcesponding proportions in area S and K were only 22 % and 35 %, respectively. The incidence of DFD meat had a stronger correlation with the level of hygiene in areas F and S than in area K. When the level of hygiene was estimated as good (= excellent + good) or fair (= satisfactory + fair + poor), the corresponding percentage frequencies of DFD meat were as follows: area F, 1.6 and 14.3; area S, 3.5 and 22.6; area K, 17.6 and 23.6.

The housing practice at the slaughterhouse influenced the incidence of DFD meat most strongly amongst the animals that originated from farms where the level of hygiene was only fair (Table 4).

During the visits to the farms an estimate was also made of the average cleanness of the animals, and the farms were placed in four classes on the basis of the results. The incidence of DFD meat in these classes was as follows: animals clean (159) 3.1 %, fairly clean (222) 9.9 %, dirty (261) 19.5 % and very dirty (51) 21.6

Table 1. The occurrence of DFD meat (%) in relation to management practices in the areas of three slaughterhouses. Number of carcasses in parentheses.

Management practice	Slaughterhouse F	S	K
Outdoors	0.0 (123)	10.5 (19)	22.4 (58)
Indoors	8.4 (226)	19.8 (111)	21.2 (156)
in pens	1.6 (126)	3.7 (27)	32.2 (62)
in standings	17.0 (100)	25.0 (84)	13.8 (94)

Table 2. The combined effect of housing practice on farms and in slaughterhouses on the occurrence of DFD meat (%).

Housing on farms	Housing in slaughterhouses: individual pen or standing		group pen	
	DFD %	n	DFD %	n
in pens	0.8	254	20.6	107
in standings	9.8	122	28.0	118
	$\chi^2 = 18.8$, $P < 0.001$		$\chi^2 = 1.67$, $0.2 > P > 0.1$	

Table 3. The occurrence of DFD meat on farms with different hygiene levels.

	Hygiene level: excellent	good	satisfactory	fair	poor
Percentage of carcasses with DFD meat	3.2	6.8	21.5	17.1	26.8
Number of carcasses	154	192	177	129	41
Number of farms	7	10	15	10	3

$\chi^2 = 39.97$, $P < 0.001$

Table 4. The combined effect of hygiene level on farms and housing practice in slaughterhouses on the incidence of DFD meat (%).

Hygiene level om farms	Housing practice in slaughterhouses: individual pen or standing		group pen	
	DFD %	n	DFD %	n
good	1.7	229	4.4	68
poor	6.8	147	33.1	157
	$\chi^2 = 6.38$, $P < 0.02$		$\chi^2 = 21.17$, $P < 0.001$	

Table 5. The humidity level in farm buildings and the incidence of DFD meat (%).

Humidity level	very high	high	low	very low
Incidence of DFD meat	26.5	17.6	10.6	2.5
Number of carcasses	83	159	216	40

$\chi^2 = 17.71$, $P < 0.001$

% ($P < 0.001$). The level of hygiene at the farm and the cleanness of the animals were correlated; the correlation coefficient for the observations made at 45 farms was $r = 0.79$.

When the farm was in the sole charge of a woman, or a woman and a man (5 farms), the incidence of DFD carcasses never exceeded 20 %, and the average incidence for these farms was 1.1 %. Among the farms in the sole charge of a man (14 farms), the incidence of DFD meat was high for 21 % of the farms (average incidence for the 14 farms 10.0 %). When the cattle were in the care of a man assisted by paid hands (26 farms), the frequency of DFD meat was high for 50 % of the farms (average incidence for the 26 farms 17.5 %).

Ventilation

In indoor production, the atmospheric humidity in the buildings where calves and fattening animals were kept was correlated with the incidence of DFD meat (Table 5).

In only 5 % of the farms could the buildings be warmed in the winter. At the other farms a drop in the outside temperature raised the atmospheric humidity in the buildings.

The records of the temperatures in the buildings made during the visits to the farms showed no correlation with the incidence of DFD meat.

The significance of the atmospheric humidity in the buildings was shown clearly by an analysis of variance model in which the factors chosen to explain the variance in the pH of the meat from animals reared indoors ($n = 420$) were: the mode of lairage at the slaughterhouse, the atmospheric humidity in the farm buildings, the housing practice at the farms (standings or pens), the slaughterhouse and the level of hygiene at the farms. The influence of each of these factors was statistically significant. The proportion of the variance explained was 29.9 %. When each of the independent variables was removed in turn from the model, the fraction of the variance explained decreased as follows: lairage at slaughterhouse 17.1 % units, atmospheric humidity 8.6 % units, housing at farms 6.3 % units, slaughterhouse 3.8 % units and hygiene at farms 1.9 % units.

Feeding

At the calf stage (2–6 months), the concentrate ration fed to the animals later yielding DFD meat had tended to be smaller than that received by the other animals: 3.3 ± 0.6 fu as compared with 3.5 ± 0.5 fu, and their concentrate ration had a lower digestible protein content than in the normal group: 11.8 ± 2.2 % vs. 12.6 ± 2.1 %. However, the variation between the areas is so great that these differences are not statistically significant.

At the fattening stage, the animals yielding DFD meat had tended to receive more roughage: 2.1 ± 0.8 fu vs. 1.8 ± 0.8 fu, and less concentrate: 5.2 ± 1.0 fu vs. 5.8 ± 1.6 fu. Concentrate also constituted a smaller proportion of the total feed units received by the DFD animals (71.2 ± 11.0 % vs. 76.0 ± 12.0 %). Again, owing to the variation between the areas, these observations are not statistically significant.

In area F, the weight at slaughter and the net growth of the DFD bulls were significantly smaller than in the normal animals, but no such differences were found between the groups in areas S and K. Age at slaughter was the same in all the groups and areas, averaging 14.2 ± 1.5 months.

Discussion

The incidence of DFD meat in the bulls of the present study was clearly lower (12.8 %) than in the material collected at the same time from the whole of Finland (26.3 %). The data from slaughterhouse F (50.4 % of the present material) contributed strongly to this difference, since the DFD value in the F material was very low (5.4 %). Slaughterhouse F was built very recently and 84 % of the animals are kept separate before slaughter. The farms on that area also specialized more intensively in rearing beef cattle. The farms were larger than the others, the level of hygiene was higher, and the growth and weight of the animals at slaughter were greater than average. The low proportion of DFD meat at slaughterhouse F, which causes the low mean value for the whole material, is chiefly explained by the mode of lairage at the slaughterhouse (PUOLANNE et al. 1981), but also by the other factors.

The correlation between the level of hygiene at the farm and the frequency of DFD meat exists independently of the mode of lairage at the slaughterhouse (Table 4), but is strongest when the animals are kept in group pens. A good level of hygiene evidently improves the animals' resistance to stress. The mechanism of this phenomenon and the significance of the separate factors involved in the level of hygiene have not yet been treated in the literature. LAWRIE (1958) and BOUISSON (1980) have reported that the incidence of DFD meat is reduced when the animals have been accustomed to physical and psychological stress. In the present study, the animals reared in unhygienic conditions did not appear to adapt better than the others to pre-slaughter stress.

The factors involved in the level of hygiene were the atmospheric humidity in the farm buildings, the cleanness of the animals and the persons in charge of the animals. The observed relations between these factors and the incidence of DFD meat clearly show the same trend as the observations on the effect of the level of hygiene. In this material the management practices were also connected with the level of hygiene. In area F most of the DFD meat came from two farms where the animals were kept in standings with a poor level of hygiene. In the same area the level of hygiene was good when the animals were reared outdoors. The contradictory data from slaughterhouse K may be partly due to the large proportion of animals from farms with group pens, which masks the influence of the other factors, and to the good level of hygiene of the farms with standings, which was superior to that at such farms in the other areas.

In area F, where the incidence of DFD meat was low because of the use of individual pens and the good level of hygiene, the growth rate of the animals and the weight at slaughter were correlated with the incidence of DFD meat. The more intensive feeding of these animals decreased the incidence of DFD meat. Only 16 % of the animals were kept in open pens at slaughterhouse F, and the connection between a high rate of growth and better resistance to stress thus seems to exist under other conditions besides those in group pens, with their hierarchical social relationships (McPHEE et al. 1963, DUCHESNE 1978).

The results of this study indicate that the measures needed to minimize the incidence of DFD meat are a change in the mode of lairage at the slaughterhouses and improvement of the level of hygiene and the environmental conditions at the beef farms.

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SELOSTUS

Tuotantoympäristötekijöiden vaikutus naudan tervalihaisuuden esiintymiseen

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Teurastusta edeltäneet rasitukset vähentävät nautojen ja erityisesti sonnien lihasten glykogeenipitoisuutta niin, että teurastuksen jälkeen lihan pH saattaa jäädä korkeaksi. Liha on tummaa, kiinteää ja kuivaa ja sitä kutsutaan tervalihaksi. Suomessa esiintyi vuosina 1979–80 tehdyn laajan selvityksen perusteella tervalihaa 26.3 %:ssa sonnien ruhoista. Säilytettäessä sonneja teurastamossa ryhmäkarsinassa ennen teurastusta esiintyy tervalihaisuutta yli kaksi kertaa enemmän kuin parressa tai yksilökarsinassa säilytettäessä. Tässä tutkimuksessa selvitettiin sonnien kasvatusnavetan olosuhteiden vaikutusta tervalihaisuuden esiintymiseen.

Aineisto kerättiin kolmen teurastamon alueelta 45 naudanlihan tuotantoon erikoistuneelta tilalta, joilta lähetettiin tutkimusjakson aikana 693 sonnia teurastukseen. 24 tunnin kuluttua teurastuksesta suoritetussa pitkän selkälihaksen pH-mittauksessa todettiin sonneista 12.8 %:lla tervalihaisuutta (pH 6.00 tai korkeampi).

Säilytystapa teurastamon navetassa vaikutti tässäkin aineistossa eniten tervalihan esiintymiseen. Sisäkasvattamoissa kasvatettujen sonnien pH-vaihtelua selittävässä varianssianalyysimallissa, jonka selitysasteeksi saatiin 29.9 %, teurastamosäilytystavan osuus mallista oli 17.1 %-yksikköä, kasvatusnavetan ilman kosteuden osuus 8.6 %-yksikköä, hoitotavan (karsina-/parsikasvatus) 6.3 %-yksikköä ja navettahygienian tason 1.9 %-yksikköä. Teurastamoiden välisen vaihtelun osuus oli mallissa 3.8 %-yksikköä.

Ulkokasvattamoissa kasvaneiden tervalihaisuus oli alhaisempi kuin sisäkasvattamoissa kasvaneiden. Havainnon tekee epävarmaksi tässä aineistossa yleinen ulkokasvattamosonnien säilytys teurastamossa yksilökarsinoissa.

Sisäkasvattamoissa kostea navettailma, huono navettahygienia ja eläinten likaisuus lisäsivät tervalihaisuuden esiintymistä. Emännän hoitaessa eläimiä yksin tai isännän kanssa yhdessä tervalihaisuutta todettiin vain 1.1 %:ssa ruhoista kun tiloilla, joissa isäntä hoiti eläimet yhdessä palkatun väen kanssa keskimääräinen tervaliha-% oli 17.5.

Sonnien kytkeminen parteen lihotuskauden aikana lisäsi tervalihaisuuden esiintymistä karsinakasvatukseen verrattuna. Eläinten joutuessa teurastamossa ryhmäkarsinaan, kasvatustapa tilalla vaikutti vain vähän tervalihaprosenttiin (parsikasvatus 28.0 %, karsinakasvatus 20.6 %). Ero oli sensijaan tilastollisesti merkitsevä teurastamon yksittäissäilytyksen jälkeen (parsikasvatus 9.8 %, karsinakasvatus 0.8 %).

Ruokinta ei tässä aineistossa vaikuttanut tilastollisesti merkitsevästi tervalihaisuuden esiintymiseen, vaikka viitteellisiä havaintoja voimakkaan väkirehuruokinnan edullisesta vaikutuksesta tehtiin.

Tämän tutkimuksen mukaan näyttää siltä, että teurastamon säilytysolosuhteiden korjaamisen jälkeen kasvatustilan hygienian ja ympäristötekijöiden parantuminen ovat tarpeen tervalihaisuuden ehkäisemiseksi.