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CICLO XXII

RISK FACTORS FOR VEAL CALVES' HEALTH PROBLEMS IDENTIFIED THROUGH THE APPLICATION OF AN ANIMAL-BASED WELFARE MONITORING SCHEME

Direttore della Scuola: Ch.mo Prof. Luigi Gallo

Coordinatore d'indirizzo: Ch.ma Prof.ssa Lucia Bailoni

Supervisore: Ch.ma Prof.ssa Flaviana Gottardo

Dottorando: Marta Brščić

...at the dividing line between the
east of my youth and the
west of my future...
~ On the road by Jack Kerouac

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ABSTRACT

Aim of this research was to study the actual health status of veal calves at the batch level and to evaluate the risk factors associated to common problems of this livestock category using part of a full animal-based welfare monitoring scheme. A cohort study was carried out on 224 veal calves' farms representative of EU production in France (50), the Netherlands (150) and Italy (24) between 2007 and 2009. Among these farms 174 reared the conventional White while 50 grew Rosé veal. The application of the welfare monitoring scheme consisting of 3 on-farm clinical/health visits and *post-mortem* inspection at slaughter permitted to obtain prevalence of respiratory and gastrointestinal (GI) disorders. Potential risk factors among environment and management-based data were obtained by an interview to the farmer. Data were submitted to statistical analyses adopting a set of procedures in GenStat that allowed descriptive analysis and stepwise risk factor multivariate analysis. In this thesis risk factor assessment was carried out on respiratory and GI parameters with overall average prevalence higher than 5%. Prevalence of calves with bloated rumen, poorer body condition, abnormal breathing and coughing were ≤5% throughout the entire fattening cycle. Nasal discharge interested 6.2, 4.8 and 6.5% of calves at the 1st, 2nd and 3rd visit, respectively. At *post-mortem* inspection pneumonia, pleuritis, poor rumen development, ruminal plaques, ruminal hyperkeratosis and abomasal pyloric-area lesions showed overall mean prevalence of 52.4% and 25.1% of lungs, 49.1%, 25.6% and 5.3% of rumens and 70.6% of abomasa, respectively. Type of veal meat production system (White vs. Rosé) showed significant differences regarding all *post-mortem* measurements (P<0.05). White veal showed a worse situation regarding GI problems compared to Rosé while the opposite was observed for the respiratory system. Risk factors for GI disorders were related to feeding. The main hazards for rumen underdevelopment in White veal calves were the low amount (≤50kgDM/head/cycle) and type of solid feed provided (maize silage, pellets/mixture vs. cereal grain). Cereal grain was associated to ruminal plaques, papillae hyperkeratinization and abomasal lesions. Considering respiratory-system problems several risk factors were identified while natural ventilation acted as a preventive measure compared to forced. In conclusion, outcome of this thesis could be implemented by farmers/industry and in further research for disease prevention/management and improvement of animal health.

Chapter 1

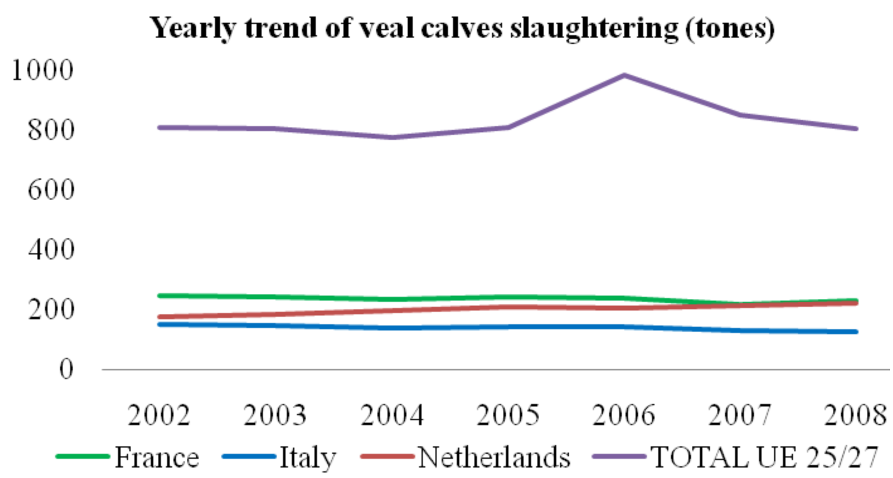
GENERAL INTRODUCTION

WHITE VEAL CALF

Veal production is a traditional fattening system of young calves with a milk based diet, which is naturally poor of iron. The main trait of this cattle rearing system is the production of soft, pale coloured meat which has an important market demand in the European Union and in North America. Veal calves production has a very long history. Several old religious books like the Bible, the Koran and the Torah report calves slaughtered for meat consumption and more recently veal meat recipes by famous Italian cooks were found in the Middle Age literature. However, the onset of the modern veal calf production has been established in the second part of the 20th century.

Nowadays, the 27 EU Member States raise about six million calves for veal meat per year. The main European producers, covering more than 60% of the total share are France with a yearly production of 1.6 million calves in 2007, the Netherlands with over 1.2 million of calves and Italy with over 870,000 calves (EUROSTAT, 2007). The yearly trend for veal meat production in the EU and in these Countries is reported in Figure 1.1.

Figure 1.1 Production of calves meat (tones) from year 2002 to 2008 in total in Europe (EU-25/27) and in particular in major producing countries: France, the Netherlands and Italy.



Calves for veal production are mostly male dairy calves that are unsuitable for beef production. They belong to pure dairy breeds (Holstein) or their crosses with beef cattle genotypes.

PRODUCTION SYSTEM

The rearing system of veal calves is similar and very standardized in all the main producing EU Countries. Calves are raised indoors in specialized fattening units under intensive rearing conditions.

FATTENING CYCLE

Suckling calves are bought from dairy farms, and then taken to fattening farms when they are 2 weeks old and they have a live weight of 45 to 60 kg. The fattening cycle lasts from 20-22 weeks in France and calves are slaughtered at a final live weight of 200-220 kg. In Italy and the Netherlands veal calves are slaughtered at an heavier live weight of 260-290 and the fattening period is prolonged up to 26-28 weeks.

HOUSING FACILITIES

Traditionally, veal calves were tethered and housed in individual undersized wooden crates (Figure 1.2), but in the EU the individual housing has been officially banned by specific regulations (91/629/EEC and 97/2/EC). Individual crates are still legal in other parts of the world, including the USA. The American Veal Association (2007) recommends that the entire veal industry converts to group housing by the end year 2017.

Figure 1.2 Traditional housing system of veal calves.

Today within EU more than 90% of the veal calves are housed in small pens (4-7 calves) while the remaining are kept in larger groups of 30-60 calves. Calves in small groups are usually housed in pens with wooden or concrete fully slatted floors and galvanized partitions (Figure 1.3). Littered pens are far less frequent since they require additional costs for bedding material and its renewal. In the 6-8 weeks upon arrival to the fattening unit, pens may be equipped with temporary partitions in order to keep each calf separated from the pen-mates. This in order to prevent cross-sucking behaviour (Figure 1.4). These separators are removed by 8 weeks so that calves can move around the pen freely. In the same housing system, the milk replacer is administered in individual buckets (Figure 1.5) or in a common trough (Figure 1.6), while solid feeds are provided using the same trough or a separate manger. An essential management procedure associated with trough milk delivery is the regular re-grouping of calves, to maintain homogeneous groups in terms of growth and drinking speed throughout the fattening period.

Large groups of calves are generally housed in pens with wooden slatted or concrete floor in combination with wooden slats (Figure 1.7). Some calves are kept on straw bedded floors or on concrete or slats covered by rubber (Figure 1.8). Milk delivery in large groups is carried out through computer-controlled automatic milk devices (AMD) (Figure 1.9) to control feeding time and intake (Bokkers and Koene, 2001). Similar devices can be used to deliver the solid feeds included in the diet.

Regardless of the pen size, the EU regulation on calf welfare has set the minimum space allowance to be given to each pen-mate which is 1.5 m^2/head for calves up to 150 kg of live weigh, 1.7 m^2 per animals weighing from 150 to 220 kg and at least 1.8 m^2 per calves above this weight.

Air temperature and humidity are controlled in the fattening units to give appropriate thermal comfort to the calves. Dedicated ventilation systems are operating during the hot and humid climate of the summer season. A proper draught is useful to maintain an adequate air quality particularly in those housing systems where liquid manure accumulates underneath the pen floor.

FEEDING PLAN

Low iron dietary supply is a prerequisite for the production of veal calves and blood haemoglobin is used to predict the meat colour since it is highly correlated with muscle

Figure 1.3 Veal calves housed in small groups.

Figure 1.4 Cross-sucking behavior in calves.

Figure 1. 5 Bucked fed veal calves.

Figure 1.6 Trough fed veal calves.

myoglobin. In order to assure an adequate meat paleness and to guarantee an acceptable calves health, the threshold of acceptance for this blood parameter has been set in the EU at a minimum of 4.5 mmol/l (European Council Directive 91/629/EEC and 97/2/EC).

Veal calves feeding is based on milk replacers (reconstituted milk which contains a variable proportion of skimmed milk and/or whey powder). All milk replacers have a low iron content and during the fattening cycle blood haemoglobin level is closely monitored to avoid any excess (dark meat) or deficiency of iron (anemia).

The milk replacers are usually delivered at a temperature of 39°C in two meals/day one in the morning and the other in the afternoon. The amount of liquid feed given to the calves is increased progressively during the fattening cycle to meet calves growth requirement.

Figure 1.7 Veal calves housed in large groups on concrete slats.

Figure 1.8 Veal calves housed in large groups on concrete floor covered with rubber mats.

Figure 1.9 Automatic milk feeding device for veal calves.

The bucket-feeding assures an individual control of milk intake (Figure 1.5), but it is more time and labour consuming for the stockman. On the contrary, the use of the trough for milk delivery can be fully automated but it has shown to amplify the drinking competition (Figure 1.6) leading to the exacerbation of the dominant-subordinate relations. Repeated regrouping is therefore necessary to limit the inhomogeneous growth of the pen-mates.

Some veal calves are still fed raw milk, like in the case of organic veal producers or the Label Rouge veal in France. In case of dairy herds, raw milk is delivered to the calves in buckets after the milking while in beef herds calves are led for suckling their dam or another cow twice a day.

According to the Commission Decision 97/182/EC, calves over 2 weeks old fattened within the EU should receive daily some fibrous feed in addition to the milk replacers (Figure 1.10). The administration of a roughage source to the traditional liquid diet has shown to reduce the frequency of abnormal oral behaviours, like tongue playing (Figure 1.11) (Mattiello *et al*., 2002), to promote a normal development of the rumen and its papillae (Morisse *et al*., 2000) and to increase rumen motility. Since solid feeds bring additional iron into the diet, veal producers are very careful in the selection of the roughage sources to be delivered to the calves (Cozzi *et al*., 2002). Maize silage, maize grain, straw and a large variety of commercial pellets consisting of both fibrous and concentrate-like sources are the most used solid feeds in the EU fattening units. The total amount of solids feed given during the fattening cycle can vary from 35 up to 250 kg of dry matter/calf but it is always far above the minimum threshold set by EU regulation in force (from 50 g to a minimum of 250 g/day from the beginning to the end of the fattening period). The housing pens are equipped with one or more drinking points since calves have shown to consume a considerable amount of water in addition to the milk replacer diet (Gottardo *et al*. 2002). The provision of drinking water is particularly recommended when calves are fed large amounts of solid feeds and during summer.

Figure 1.10 Veal calves eating solid feeds.

Figure 1.11 Tongue playing behavior in veal calf.

ROSÉ VEAL

Several systems exist across Europe that lead to the production of so-called "pink or rosé veal meat". The main differences from the conventional production of white veal are that the calves are reared for a longer period and they receive higher amounts of solid feeds with no iron restriction.
Cattle breed used for rosé veal calves production vary across Europe. In the Netherlands and UK they are mostly male dairy calves while in France and Spain, calves are more often from suckler beef breeds.

PRODUCTION SYSTEM

The rearing system of the pink veal calves is different and less standardized than that of the conventional white veal. Calves are fed raw milk or milk replacers in the first part of the fattening cycle but then they are weaned and fed a diet made of forage and concentrates. In some Countries, like France and UK, calves are reared with their dam in a free-range environment. In Holland, calves are housed in large pens of 40-80 calves with a space allowance of 1.8 m^2 per calf from the start of the fattening period. Calves are nipple fed via computerised, automatic feeding stations (40 calves per feeding station) and after weaning calves receive ad lib a fattening diet based on maize silage and by-products. Rosé veal diets have no limitations for the iron supply and, consequently, calves develop normal haemoglobin levels and their meat has a darker "pink" colour (European Food Safety Authority, 2007).
The pink veal calf is sold when it is heavier (and therefore older) than the white veal calf. The age at slaughter can vary from calves of 5-8 months to "baby beef" young bulls of 8-11 months depending on breed and production rate (Centre d'Information des Viandes, 2009). In Spain, pink veal calf is known as 'ternera' and it is slaughtered at an age of 9-12 months, with a carcass weight of 180 to 240 kg. Since the forestomachs are normally developed, dressing percentage of pink veal calves is lower than conventional white calves (55 vs. 60%).
In many Countries, rosé veal meat is certified and labelled (organic, etc.) to help consumers to distinguish it from the meat from more adult beef bulls or steers.

THE WELFARE ISSUE FOR VEAL CALVES

The traditional rearing system of veal calves has been strongly criticized because of poor animal welfare (Broom, 1991). Isolation and the lack of freedom to move of calves tethered in individual narrow crates, the administration of a diet based on milk replacers without any provision of solid feeds throughout the fattening cycle and the low blood hemoglobin levels were the main issues addressed against these system. The need for alternative to traditional calves raising systems has been recognized also by the industry. The European legislation in force through the ban of the individual crates, the mandatory provision of some dietary roughage, and the set of a minimum threshold for blood hemoglobin made a significant step forward for the welfare of veal calves. However, there is still an open debate on several housing and management factors that may impair calves health and welfare. As regards the housing facilities, additional scientific knowledge are required to establish if the existing space allowance and the fully slatted floor are adequate to fulfill calves needs. The scientific report of the European Food Safety Authority on the risks of poor welfare in intensive calf farming systems (2007) has identified inadequate ventilation, airflow and air temperature as major environmental risk factors. In the same document, potential risk factors related to calves management have been identified in the inadequate intake of colostrums, the continuous restocking and mixing of calves from different origins. There is a need for additional information in the field of nutrition, to better balance the provision of solid feeds in terms of quality and quantity. Last but not least, the need to promote a significant professional growth of the stockman addressed to the adoption of more welfare friendly farm practices.

PUBLIC OPINION ON ANIMAL WELFARE: GAP BETWEEN PERCEPION AND VEAL CALVES FARMING REALITY OR JUSTIFIED CONCERNS?

Although the relevant welfare improvements brought by the legislation for the protection of calves, the intensive farming systems of this livestock category has been blamed by the public opinion for the insufficient animal welfare.

Animal welfare was first of interest in the early nineteen-sixties in order to guarantee healthy food for humans rather than considered important for animals' well being itself.

According to Rollin (2007) defining welfare of livestock became an issue when the nature of agriculture changed from husbandry (small family-run realities) to industrialized intensive farming. Under intensive conditions often farm environment edges between physiological and pathological. Industrialization made bigger cultural and commercial barriers that worsened furthermore the communication between farmers and consumers resulting in a wider divergence between the reality of the modern animal production and its perception by the public (Buller and Morris, 2003). Frauds and health problems such as foot and mouth disease, BSE, avian influenza and, swine fever focused the media attention on farms rearing conditions, reporting to public the “truth” behind certain production systems and the high stocking rate that characterizes them. Nowadays, there is a growing awareness that animal production is more than just an industry and, it is common opinion that the intensive rearing is negatively related to the animal well-being (Steenkamp and van Trijp, 1996). On the other side, for the large majority of the urbanized world, farm-animal welfare is related to a ‘natural’ behaviour in a ‘natural’ environment (Miele *et al*., 2007).

Evidence of the ethical concern regarding veal calves welfare are several campaigns, initiatives, and actions that have been and are currently carried out in Europe against white veal meat (e.g. Freedom Food of the Royal Society for the Prevention of Cruelty to Animals, Compassion in World Farming, and Good Veal Campaign). Moreover, the increasing demand for welfare and environment friendly products confirms that consumers require food that guarantees sustainability for people, animal welfare and environment, besides hygiene and safety (Webster *et al*., 2004; Eurobarometer, 2007). Consistent with citizens’ attention, several retailers and supermarket chains across Europe stop selling veal meat (www.expatica.com, 2009). Active support against veal production came from high profile figures like Sarah Brown, wife of the current Prime Minister of the UK, who declined to eat white veal meat at the recent G8 summit 2009 held in L'Aquila (IT) due to her longstanding objections to the cruel calves’ rearing conditions. Her description of the rearing system as “a very cruel practice, whereby calves are kept in crates and are fed a diet of milk to keep their flesh white" was, however, contested by British farming groups who pointed out that calves are now raised in much better conditions (www.timesonline.co.uk, 2009). This could be interpreted from different points of view: it could confirm the relevance of the gap between public's perception and farming reality or it could confirm that, despite all the work done and the recognition of animals as sentient beings (Duncan, 2006), the development of a sustainable production system that fulfils efficiently public expectations is still an utopia.

AIM AND OUTLINE OF THE DISSERTATION

This study was carried out within the Welfare Quality® project (www.welfarequality.net, 2009) that aimed at developing European standards for on-farm welfare assessment and product information systems as well as practical strategies to improve animal welfare. Aims of this thesis were to:

- study the prevalence of clinical/health problems in veal calves through the application of a full animal-based welfare monitoring scheme on 224 veal calves' rearing units in the Netherlands, France and Italy between summer 2007 and spring 2009
- compare prevalence of main problems between White and Rosé meat production system
- identify the risk factors that impair calves health status.

General introduction (Chapter 1) describes the main changes that occurred with the coming in force of the regulation for calves' protection in Europe and the features of nowadays veal calves production pointing out differences between white and rosé veal rearing systems. Moreover, in order to understand why concern is still addressed towards veal calves' welfare, perception from the public opinion is explained.

Since a risk factor is a variable associated with an increased risk of disease or infection, before proceeding with the experimental part of the thesis, a list of potential risk factors that are still present in the new conventional veal calves farms are reviewed in Chapter 2, along with those for beef cattle.

In Chapter 3, the protocols and measurements of the trial are described within their Welfare Quality® project framework. Even though each measure was described, the rationale behind its choice was not considered into details in General materials and methods of this thesis. Feasibility, repeatability and inter-observer reliability of the measures and the complete methodological approach will be considered elsewhere in further publications.

Prevalence of respiratory disorders recorded either *in vivo* during the on-farm clinical/health visits or the *post-mortem* inspections carried out at the time of slaughter are described and risk factors are investigated in Chapter 4. After a first comparison of the health status between the two types of veal meat production (White vs. Rosé), critical points for important problems are scrutinized among resource-based measures and dietary and husbandry choices. The same strategy was adopted also in Chapter 5 where the evaluation of risk factors for animal health was carried out on relevant problems at the gastrointestinal system with particular emphasis to the *post-mortem* measurements and their association with dietary and feeding factors.

General conclusion (Chapter 6) presents the robust points and weaknesses of the approach adopted in this research and gives a general scheme for the identification and understanding of the underlying factors that drive to increased risks of developing certain problems offering some practical interpretation for potential end-users.

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Chapter 2

MAIN CRITICAL FACTORS FOR THE WELFARE OF BEEF CATTLE AND VEAL CALVES RAISED UNDER INTENSIVE REARING SYSTEMS IN ITALY:

A REVIEW

MAIN CRITICAL FACTORS FOR THE WELFARE OF BEEF CATTLE AND VEAL CALVES RAISED UNDER INTENSIVE REARING SYSTEMS IN ITALY: A REVIEW

Giulio Cozzi, Marta Brščić, Flaviana Gottardo

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INTRODUCTION

Animal welfare is impaired when normal biological functions are afflicted but even healthy, normally growing and reproducing animals may be in a poor welfare status if they experience suffering and are reared in inadequate conditions (Mendl, 2001). Nowadays, it is common opinion that rearing systems with a high stocking rate are negatively related to the animal well being since for the large majority of the urbanized world the perception of farm animal welfare is related to a ‘natural’ behaviour in a ‘natural’ environment.

The basal needs of farm animals should be assured by allowing a free access to adequate quantity of feed and fresh water, by providing a suitable rearing environment and by avoiding physical pain or any kind of suffering (Webster, 2001). Specific legislations on animal welfare exists for several categories of farm animals by the European Union. In the case of cattle, a regulation is in force for the protection of veal calves, imposing their group housing and the provision of a small amount of fibrous feeds in addition to the liquid diet (European Council Directive 91/629/EC and 97/2/EC). No explicit rules are instead in force for beef cattle and the only reference document is the report by the Scientific Committee on Animal Health and Animal Welfare (SCAHAW, 2001) that made a detailed survey on the current rearing systems identifying several housing and management solutions to improve health and care of these animals. Despite the large number of studies carried out on this topic, still many causes of poor welfare can be found in beef cattle and veal calves farms and sustainable rearing systems are still to be established (McGlone, 2001). The present review aims at describing the main causes of poor welfare that may be found in intensive beef cattle and veal calves farms in Italy.

INTENSIVE BEEF CATTLE PRODUCTION IN ITALY

According to the European statistics (OFIVAL, 2007), in the year 2005 Italy represented the third main contributor (11.4%) to the total cattle meat produced within the 25 EU Countries following France (22.5%) and Germany (15.3%). However, the self-supply obtained by calves born and raised for meat production in the Country covered only little more than 30% of the national demand. Thirty percent of the national deficit was covered by importing fresh and frozen meat from animals raised and slaughtered abroad, mainly in France and Spain. The remaining 40% was provided by living young bulls and heifers which were imported to be finished in the Italian fattening units. In 2005, about 1 million heads were transferred to Italy from their native countries (Cozzi, 2007). France is the major supplier of these imported young cattle followed by Eastern European countries. The prime category of the imported beef cattle from France is the "*broutard*", young bulls and heifers 8-12 months old belonging to French pure beef breeds Charolais, Limosine, Blonde d'Aquitaine or their crosses with dual purpose breeds (SCAHAW, 2001). Polish Friesian and Simmental are the main breeds imported from East-Europe. Once at destination, cattle are fattened in specialized farms under intensive rearing conditions. Most of these fattening units are located in the Po Valley and they adopt the indoor loose housing of the animals in multiple pens. Fattening bulls and heifers are fed high concentrate diets which are provided as total mixed rations (TMR) in order to reduce the risk of the occurrence of rumen and metabolic acidosis. Maize is the main crop used for the formulation of these diets and it is included either as dried ground meal or as high moisture ear silage and whole plant silage.

ENVIRONMENTAL RESOURCES AND CATTLE WELFARE

From an animal welfare perspective, the loose housing in groups adopted in the Italian fattening units must be considered an acceptable solution because it allows locomotion (Kempkens and Boxberger, 1987) and the development of social behaviours among pen-mates. Feed intake has also shown to be increased when cattle are loose housed in comparison to the permanent tethering (Ingvartsen and Andersen, 1993). However in many farms, the pen size is insufficient due to the over-crowding and therefore the space allowance is one of the most critical factors impairing beef cattle welfare. According to Ingvartsen and Andersen (1993), a limited space allowance results in a low feed intake and daily gain worsening the feed conversion ratio of the animals. Aggressive behaviours have shown to increase when fattening bulls are housed with an insufficient space allowance. In this housing condition, there is also a reduction of the time spent resting, eating and ruminating particularly by the subordinate animals which cope with more difficulty with the dominant pen-mates (Gottardo *et al*., 2003; Bouissou and Boissy, 2005).

Even cattle health is worsened by an insufficient space allowance which was considered the main cause of lesions such as trauma on bone and joint, osteoarthropathies, prepuce injury and tail tip necrosis observed in fattening cattle (Groth, 1985). Beranger (1986) reported mortality around 1% when space allowance was 3 m^2/head while it more than doubled when space was less than 2.5 m^2/head. On the contrary Sundrum and Rubelowski (2001) found a low correlation between the incidence of early losses and either space allowance or floor quality indicating that many other aspects were relevant besides pen design criteria. Based on several studies, SCAHAW (2001) has suggested at least 3 m^2/head as tolerable space allowance for bulls weighing 500 kg, to be increased by 0.5 m^2/head for every additional 100 kg of live weight.

Another issue to be considered as a critical point for the welfare of beef cattle is the pen floor type and quality. A suitable housing system should assure to the animal the possibility to move and lay or stand freely on a not slippery floor (Veissier *et al*., 1999). Inadequate floor conditions, besides changing animals' normal laying/standing and walking behaviours, often cause injuries. The predominant type of floor in the Italian intensive beef cattle farms is the fully slatted, because it does not require any bedding material and it has a lower labour cost to remove slurry. Littered pens are adopted for the fattening of bulls slaughtered at heavy live weights. Fully slatted floors compared to deep litter systems, has shown to impair bulls' behaviour by increasing abnormal positions both when standing and lying (Wierenga, 1987), and by enhancing the frequency of leg and foot injuries (Murphy *et al*., 1987), tail tip necrosis and early losses, especially when it is associated to a low space allowance (Ingvartsen and Andersen, 1993; Metzner *et al*., 1994; Schrader *et al*., 2001). However, a recent study carried out by Gottardo *et al*. (2003) in an Italian beef cattle farm, reported satisfactory health status and similar values for several blood indicators of chronic stress between bulls housed on fully slatted floor and animals on straw bedded floor with the same space allowance (3 m^2/head). Straw bedding allowed bulls to better perform their natural social behaviour during the feeding time by increasing eating frequency and the simultaneous presence of more bulls at the manger.

Cleanliness can be used as indirect measure of cattle welfare since it has been shown to be worsen either in animals suffering of gastrointestinal disorders or in case of a poor quality of farm stockmanship. In the study of Gottardo *et al*. (2003), bulls on deep litter were always dirtier than those on slats due to an insufficient frequency of its renewal. Therefore, in case of short supply of bedding material the slatted floor system has proved to be an effective compromise to the deep bedding (Kelly and Webster, 1989). Furthermore, when using the deep bedding system, the adoption of sloped floors should be avoided since it has shown a high incidence of lameness (ITEB, 1983; Cozzi *et al*., 2005a).

The space at the manger may be another critical factor for beef cattle welfare because, if restricted, it can negatively affect the feeding time increasing competition and stress among pen-mates (Longenbach *et al*., 1999). Reducing the number of feeding places to less than 1 per animal decreases also their performances (Ingvartsen and Andersen, 1993). The SCAHAW report (2001) suggests a feeding trough space allowance ranging from 0.6 to 0.7 m/head for fattening cattle weighing 500 kg in loose housing systems. However, Gottardo *et al*. (2004) proved that this parameter becomes less relevant when bulls are truly fed *ad libitum* while the indication should be followed if the diet is rationed (Faulkner and Berger, 2003). Besides the allowance of space, mangers have to be designed in a way that all the animals can easily and comfortably achieve the distributed feed (Veissier *et al*., 1999).

Beef cattle should be provided with clean fresh water in order to fully meet their water requirements (Webster, 2001). Cattle water consumption depends on the dry matter content and composition of the diet as well as on the environmental temperature and humidity (Philips, 1993; NRC, 2000). In the literature, there are no specific indications about the number or the size of the water providers to be installed in multiple pens for beef cattle. However, it is rational to recommend that they should increase according to the number of animals kept within the same pen. According to NRC (2000), the water intake of finishing bulls (450 kg of live-weight) increases from 48 up to 78 l/d when temperatures raise from 21.1 to 32.2°C. Therefore, additional drinking points should be provided during the hot season to fulfil the greater demand of water by beef cattle exposed to heat stress. A recent survey, carried out by Mazzenga *et al*. (2006) in 20

Italian intensive beef cattle farms showed that in none of them there was an inclusion of additional water providers during the hot season. The quality of drinking water should also be considered but no specific reference values for its temperature, chemical and organoleptic characteristics are available. However, there is a common opinion among practitioners that they should not be much different from human drinking water standards.

Critical summer weather conditions have also shown to impair the animal welfare by increasing body temperature and reducing feed intake (Lefcourt and Adams, 1996). According to the SCAHAW report (2001), temperatures above 27°C at a relative humidity >80% or above 30°C at lower moisture impair cattle welfare. Under intensive rearing systems, the effect of the hot climate on the beef cattle response can be exacerbated by the heat increment induced by feeding diets rich in concentrates (Mader, 2003). The Temperature Humidity Index (THI) proposed by Armstrong (1994) could be an effective tool to assess the potential stressful conditions for beef cattle. A value of THI greater than 74 is considered the minimum threshold of heat stress for beef cattle (Davis *et al.*, 2003; Holt *et al.*, 2004) and this climate condition can be frequently experienced by cattle raised in the Po Valley (Mazzenga *et al.*, 2006). Farm design criteria should therefore consider solutions capable to allow animals to better cope with these stressful conditions including appropriate ventilation and cooling systems. A good ventilation system should also provide good air quality by lowering noxious gases concentrations. Levels of NH_3 above 20 ppm and above 5000 ppm for CO_2 are considered harmful for both animals and farmers (SCAHAW, 2001). At this regard, direct measures of both gasses in a sample of Italian beef farms during summer and winter showed that their concentrations were far below the risk threshold (Mazzenga *et al.*, 2006).

Housing structures should avoid crossbars used to prevent mounting. Such bars are impairing welfare because they are adverse to the animals' freedom to express normal behaviours (Webster, 2001). Another critical factor for the Italian beef farms is the almost complete absence of moving and loading facilities for cattle (Nanni Costa *et al.*, 2001). This fact has negative implications both on animal welfare and meat quality. Moving and handling cattle without dedicated alleys, loading ramps and restraint structures makes animals nervous and less cooperative, increasing the stockmen's risk of being injured (Grandin, 1997; Gustafsson, 1997). The use of electric prods to speed up the moving and loading operations does not help and it should be avoided since it impairs cattle welfare and, at the time of the slaughter, it enhances the risk of a severe carcass depreciation due to bruising or to the occurrence of dark cutting beef (SCAHAW, 2002).

FEEDING PLAN AND CATTLE WELFARE

A satisfactory feeding plan should deliver to all the pen-mates the right quantity of a diet made with good quality ingredients. Therefore the ration should be formulated to fully meet the nutritional requirements of the animals according to their breed, bodyweight and daily gain (INRA, 1988; NRC, 2000). At this regard, a survey carried out by Gottardo *et al*., (2002a) on 17 intensive Italian beef cattle farms observed non satisfactory feeding conditions for most of them. Energy and protein concentrations of the TMR were frequently above the target needed according to the cattle requirements. This represents a stress factor because a large amount of readily fermentable organic matter decreases ruminal pH and may lead to subclinical or clinical acidosis (Fiems *et al*., 1999). Cattle fed high amounts of concentrates have also an increased risk of developing liver abscesses (Ingvartsen and Andersen, 1993) and laminitis (De Campeneere *et al*., 2002). Another critical point observed in the same survey was the insufficient amount of diet distributed, since in many fattening units there was no feed residue at the manger before the provision of the new TMR the next day (Gottardo *et al*., 2002a). This feeding condition may not assure the maximum intake to all the pen-mates and therefore it could increase the negative interactions among them resulting in a likely inhomogeneous growth between dominant and subordinate bulls.

Periodic chemical analyses should warranty for the quality of the feed ingredients of the diet but this good management practice has shown to be carried out only by a minor number of Italian beef farmers (Gottardo and Cozzi, 2005). Particular attention should be addressed towards the storage of the wet feedstuffs such as the ensiled forage and grains in order to keep them unaltered and toxin-free.

The particle size of the TMR is another important parameter which can affect ingestive behaviour and rumination in beef cattle (Cozzi and Gottardo, 2005). Cozzi *et al*. (2007), in a large study on the feeding situation of finishing beef cattle in Italy, recently showed that diets have a high percentage of fine particles (< 8mm) which has a limited capacity to promote chewing (Mertens, 1997). In many farms, a significant loss of long particles (> 13mm) occurs during the TMR preparation due to the damage of the long particles of maize silage. Therefore, a more careful handling of this roughage could reduce its damage and the consequent loss of long particles, which at the moment imposes the inclusion of straw or other long fibre roughages in the TMR for rumination purpose.

QUALITY OF THE STOCKMANSHIP

The main critical factor for beef cattle welfare to be considered when discussing the quality of the stockmanship is the human-animal interaction. A positive attitude of the stockperson in handling and taking care of the animals seems to improve cattle welfare. A specific training of the farm crew should be therefore encouraged (Boivin *et al*., 2003). Under intensive rearing systems, where a single stockperson is in charge of a large number of animals, the opportunity to built positive relationships between humans and animals is limited by the fact that contacts are not frequent and they are usually associated to frightening practices for cattle like in case of medical treatments, prophylaxis or grouping etc. (Waiblinger *et al*., 2006).

Knowledge of cattle ethologic patterns and social behaviour could be useful for the stockman in order to establish a trustful relation with its animals. Therefore, beef farmers should avoid to regroup the animals during the fattening period in order to keep unaltered the hierarchy and especially the dominant-subordinate relationships established within each pen (Boivin *et al*., 2003; Bouissou and Boissy, 2005; Mounier *et al*., 2006). On the contrary, a good management practice should advice towards the quick transfer of sick, lame or recumbent bulls to an appropriate infirmary pen since their early separation from the healthy pen-mates avoids further stress and injuries from dominant aggressive animals.

Tail docking and other surgical mutilation have shown to cause fear, pain and distress to beef cattle (Mellor and Stafford,1999) and therefore they should be avoided. Proper management decisions, like the provision of a suitable feeding plan combined with adequate flooring and space allowance, have shown to be effective preventing measures to reduce the incidence of tip necrosis avoiding tail docking (Metzner *et al.*, 1994).

A good quality of the stockmanship should also consider the protection of the animals against endo- and ecto-parasites and rodents, as well as the frequent cleaning of housing structures, mangers and waterers. Nowadays, official methods are available for the assessment of cattle body cleanliness (MAFF, 1998) and this measure, besides being an important trait for the evaluation of beef cattle welfare, could represent an effective tool to judge the stockmanship quality.

VEAL CALVES PRODUCTION IN ITALY

The veal calves reared and slaughtered in Italy cover about 70% of the total national demand of veal meat (Cozzi, 2007). The remaining 30% is satisfied by imported veal meat from Holland and France. The Italian production is based on the rearing of dairy breeds male calves, either national or imported from Poland, France and Germany. In the past (before 2004), the traditional rearing system was characterized by the indoor housing of the calves in individual crates with about 1 m^2 of space allowance and by the provision of an all-liquid diet. The pale colour of the meat was the result of a low iron feeding plan along with the use of wooden facilities (Andrighetto *et al.*, 1999). This rearing system was similar to those adopted by the two other main European producers of veal meat: Holland and France. Isolation, reduced space allowance and the lack of solid feeds were considered the main critical issues of this rearing system impairing calves behaviour, welfare and health (Broom, 1991; Le Neidre, 1993). These criticisms led to the draft of specific European Council Directives (91/629/EEC and 97/2/EC) with the mandatory introduction of the group housing and the provision of fiber feeds in addition to the liquid diet.

Today, 90% of the Italian farms raise veal calves in small groups housed within close barn in pens with wooden or concrete fully slatted floors. In these pens, the milk replacer is administered individually in buckets or in a common trough, while solid feeds are provided using the same trough or a separate manger. The use of automatic feeding systems for large groups of calves is less frequent and it is adopted only by 10% of the Italian fattening units. Despite these changes adopted in the production system, still several risk factors of poor calves welfare can be identified at the farm level in Italy, as well as in the other European Countries.

ENVIRONMENTAL RESOURCES AND CALF WELFARE

There is no doubt about the improvement of calves welfare given by the group housing since animals have now the opportunity to move freely and perform social behaviours as playing and grooming (Verga *et al*., 2000; Babu *et al*., 2004). Moreover, calves in groups reduced the frequencies of abnormal behaviours as the tongue-playing that are indicators of social deprivation, coping stress or nutritional and environmental deficiency (Andrighetto *et al*., 1999). Calves responded positively to this improved environment since their growth performance were not worsened by the increased energy expenditure required for locomotion (Andrighetto *et al*., 1999; Xiccato *et al*., 2002). However, there is still some concern about the space allowance given to each calf by the regulation in force (1.5 m^2/head for calves up to 150 kg of live weigh, 1.7 m^2 per animal weighing from 150 to 220 kg and at least 1.8 m^2 per each animal above this weight). From an ethological point of view, space should be enough to allow grooming, turning around and a comfortable resting with two or more limbs stretched out to all the pen-mates (Broom, 1991). Nowadays, there is a lack of scientific information about this issue as stated by EFSA (2006) in a recent scientific report. It has been recently demonstrated that the access to an outdoor pen improved growth performance of veal calves during winter in comparison to animals keep indoors. However this positive effect was not observed in the summer (Morel and Schick, 2004).

Regarding the type of floor, wooden slats offer a better thermal comfort than concrete slats during the cold season, but they must not be slippery, too hard or splintery to change animals' locomotion behaviours or cause lesions. Consistent with more adult cattle, there are opinions that the inclusion of a resting area with permanent bedding could improve veal calf welfare. However, no specific scientific indications are available about the size of this area and the type of bedding material to be used.

The number of animals per pen may be another critical point for calves welfare because of the greater antagonistic behaviours observed in overcrowded pens. The correct choice for this parameter should be based on the pen size but mainly on the feed supply system.

In fact, when animals are bucket-fed a pen size seems to loose importance if an adequate space is provided to all the pen-mates (Gottardo *et al*., 2005). On the contrary, in the automatic teat-based milking systems, in addition to the space per calf, there must be an adequate ratio between the number of teats and the number of pen-mates. Commercially available computerized calf feeders are typically set with one teat serving more than 20 calves. Results by Von Keyserlingk *et al*. (2004) have shown that this practice may cause increased competition among calves, reducing feeding time and milk intake. Consistent with these findings, calves fed by computer-controlled milk feeders showed more frequent aggressions and displacements around the feeding station, as well as a high occurrence of cross-sucking (Jensen, 2003).

According to its size, the pen design should also consider the presence of one or more drinking points since calves have shown to consume a considerable amount of water in addition to the milk replacer diet (Ruis Heutinck and Van Reenen, 2000). Gottardo *et al*. (2002b) observed that drinking water did not cover a shortage in calves water requirement, but it acted more like an environmental enrichment preventing the arousal of nonnutritive oral behaviors. The provision of drinking water is particularly advisable now that calves are fed small amounts of solid feeds for welfare purpose, especially during the warm season.

Air temperature and humidity should be appropriate to give calves a suitable thermal comfort. For this reason, dedicated cooling systems are necessary especially during summer in the hot and humid climate of northern Italy, where the majority of the veal farms are located. Air quality is noteworthy for epidemiologic issues, indeed the presence of draught is related to a lower incidence of calves suffering from infectious diseases (Lungborg *et al*., 2005). Draught is useful as well to maintain the air ammonia levels below the maximum critical threshold of 20 ppm in these housing systems where the liquid manure accumulates underneath the pen floor. Results by Lungborg *et al*. (2005) have shown that the dangerous air ammonia concentration for calves is much lower since values below 6 ppm were associated to an increased risk for respiratory diseases. However, air speed should not exceed 0.2 m/s because calves exposed to high speed draught showed a higher risk for respiratory sounds (Lungborg *et al*., 2005).

Like beef cattle farms, calves fattening units in Italy are generally lacking dedicated moving and loading facilities leading to similar consequences for animal health and welfare, carcass and meat quality and stockmen safety.

BLOOD HAEMOGLOBIN LEVEL

Low iron dietary supply is a prerequisite for the production of veal calves and blood haemoglobin is used to predict the meat colour since it is highly correlated with muscle myoglobin. In order to assure an adequate paleness of the meat and to guarantee an acceptable calves health, the threshold of acceptance for this blood parameter was set at a minimum of 4.5 mmol/l (European Council Directive 91/629/EEC and 97/2/EC). The locomotion allowed by the group housing has shown to stimulate erythro-poiesis (Reece and Hotchkiss, 1987; Andrighetto *et al*., 1999). Increased haemoglobin levels have been measured with the provision of some solid feeds like cereal-straw pellets or dried beet pulps (Morisse *et al*., 1999; Cozzi *et al*., 2002a) and with the administration of milk replacers in which milk powder was substituted with vegetable sources (Andrighetto *et al*., 1996). All these results explain the reluctance of many producers towards the introduction of the EU regulations since the market is still paying premium prices for whiter meat. The veal calf production is therefore a clear example of the need for a parallel consumer education in order to allow a winning introduction of welfare friendly rearing systems for farm animals.

SOLID FEED PROVISION

In order to fulfil the physiological and behavioural demands of the calf the Council Directive 97/2/EC dictates that calves must be provided with increasing amounts of fibrous feed from 50 g/head/d at 8 weeks of age to 250 g/head/d at 20 weeks, besides the regular liquid diet. Several studies have indeed demonstrated that the addition of a roughage source to the traditional liquid diet reduced abnormal oral behaviours (Vessier *et al*., 1998; Morisse *et al*., 1999; Mattiello *et al*., 2002; Di Giancamillo *et al*., 2003), promoted a normal development of the rumen and its papillae (Morisse *et al*., 1999, 2000) and increased rumen motility and therefore it was likely the reason for the lowered number of hair balls (Morisse *et al*., 2000; Cozzi *et al*., 2002b). However the quality of the fibrous sources must have adequate roughness and particle size. Too rough fibrous feeds may increase the incidence of lesions of the abomasums' walls or if not adequately grounded they can worsen the abomasal erosions, ulcers and scars (Cozzi *et al*., 2002b, Mattiello *et al*., 2002). On the contrary, an inappropriate length of the roughage may have a limited capacity to stimulate rumination (Morisse *et al*., 2000). Considering the forestomach development, supplementing concentrates differing in carbohydrate composition to veal calves increased the empty rumen weight but it enhanced the incidence of coalescing rumen papillae (Suáres *et al*., 2006).

The quality of the liquid diet should be controlled by a periodic chemical analysis of the milk replacer and by a regular on-farm check of the temperature at the time of its administration. This latter practice has shown to reduce the risk of occurrence of diarrhoea (Lungborg *et al*., 2005).

HUMAN-ANIMAL INTERACTION AND MANAGEMENT

Scientific evidences have proved that veal calves benefit from a positive attitude of the stockman (Boivin *et al*., 2003). The disease level was lower in calves fattening units where the farmer behaved sympathetically towards the calves and had positive attitude towards the importance of cleaning (Lensink *et al*., 2001b). Calves receiving positive human contacts during the rearing period were less fearful when approached by known or unknown people (Lensink *et al*., 2000) and during handling and transport (Lensink *et al*., 2001a).

Continuous fear causes stress and it is negatively related to welfare (Raussi *et al*., 2003). Animals should be used to humane presence, vocal interactions, physical contact and they should be rewarded by feeding (Waiblinger *et al*., 2006). The establishment of a positive human-calf interaction is likely to make less stressful invasive routine practices like the blood collection for haemoglobin control.

Farm management decisions can affect calves welfare, like in the case of the choice of the feed supply system for small groups. In comparison to the trough, the bucket-feeding assures the individual control of the milk intake for all the pen-mates. However, this system is more time and labour consuming for the stockman. On the contrary, the trough feeding amplifies the drinking competition at the time of the meal leading to the exacerbation of the dominant-subordinate relations. Repeated regrouping is therefore necessary to limit the inhomogeneous growth of the entire batch. Different from more adult cattle (Raussi *et al*., 2005), a study by Veissier *et al*. (2001) observed that this practice did not impair calves health and growth. However the same authors suggested to carefully apply this finding to commercial farms in which rearing conditions are different from those adopted in their research.

Like in the beef farms, a good management of the calves fattening units should pay attention to the cleanliness of animals and of housing and feeding facilities, as well as to prevent calves from parasites and rodents.

CONCLUSIONS

Italy has still a prominent position in the European scenario of the beef cattle and veal calves production. But the maintenance of a significant domestic production requires the identification and adoption of effective solutions capable to overcome the present critical factors for the welfare of these animals. At least for beef cattle farms, these solutions should be tailor made to the existing systems of production which are not always similar to those of other European countries. Therefore, Italian beef producers should built a strong partnership with the scientific community in order to support the future improvements with a robust scientific knowledge, which is today required by the Official Institutions.

The present review has discussed several cattle welfare limiting issues related to the farm environment and facilities that will be mostly solved by future advances in farm technology and engineering. A more difficult step will be the achievement of a significant improvement of the stockmen skills addressed to the adoption of welfare friendly farm practices.

The success of any further improvement in farm animal welfare is however strongly dependent on two factors. First of all, farmers must consider the adoption of welfare friendly practices as an opportunity to increase their net income. On the other hand, a proper consumer education towards the purchase of welfare friendly beef and veal meat appears the strongest tool to drive the entire productive chain to the welfare target.

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Chapter 3

GENERAL MATERIALS AND METHODS

FRAMEWORK

These studies were carried out within the Welfare Quality® project (www.welfarequality.net, 2009) that aimed at developing European standards for on-farm welfare assessment. One of the main objectives of the project was the development of standardized monitoring system for different categories of selected farm animal species:

- dairy cattle
- beef cattle
- veal calves
- laying hens
- broilers
- fattening pigs
- sows

The task has been developed according to a set of fundamental principles:

- the exclusive use of valid and reliable measures;
- the possibility to be applied on all the existing rearing systems;
- the requirement of a reasonable time budget;
- the easy use by a single trained assessor.

A further basic principle of the proposed methodology was the exclusion of all the measures that require invasive procedure since they may cause a stress response affecting the measure of interest (Stewart *et al*., 2005). Therefore all the physiological parameters obtained from blood sampling or from other minimal invasive handling of the animals were not considered.

The rationale of the protocol considered animal-based measures as the main tool to assess animal welfare and their integration with some resource and management measures capable to identify causes of poor welfare. The first step for the development of the protocol was the definition of 12 sub-criteria that can be clustered in 4 main descriptors of animal welfare as shown in Table 3.1.

Table 3.1 General framework of the animal welfare assessment scheme in Welfare Quality®.

Principle	Welfare Criteria	
Good feeding	1	Absence of prolonged hunger
	2	Absence of prolonged thirst
Good housing	3	Comfort around resting
	4	Thermal comfort
	5	Ease of movement
Good health	6	Absence of injuries
	7	Absence of disease
	8	Absence of pain induced by management procedures
Appropriate behaviour	9	Expression of social behaviours
	10	Expression of other behaviours
	11	Good human-animal relationship
	12	Positive emotional state

A wide list of potential measures was then created for each sub-criteria considering all the parameters available from the scientific literature. This list was then submitted to a group of experts for each category of farm animals in order to skip the parameters which were not considered reliable and feasible on commercial farms. The final outcome was the proposal of a full monitoring scheme which in the case of veal calves included the measurements reported in Table 3.2.

A further action towards the development of the final monitoring scheme has been the testing of this prototype on a large sample of commercial farms located in different European countries. Regarding veal calves a cross-sectional study was carried out on one batch of veal calves per each of 224 farms, throughout one rearing cycle between summer 2007 and spring 2009.

In order to meet one of the main aims of an animal welfare monitoring scheme, a supplementary step towards the set-up of a fully validated assessment method for veal calves was the identification of risk factors that impair their health and welfare (Sørensen *et al.*, 2001, Botreau *et al.*, 2007). However, in the animal welfare research field there are no existing international guidelines for the risk assessment (Müller-Graf *et al.*, 2008).

Once risk factors are recognized and ranked, development of advices, accurate plans, and treatments for disease prevention and management measures would be easier and more efficient. The consequent accomplishment of solutions and advises to overcome the

Table 3.2 Measures for veal calves at the farm level and at the slaughterhouse (Welfare Quality®, 2009).

	Welfare Criteria		Measures
Good feeding	1	Absence of prolonged hunger	Body condition
	2	Absence of prolonged thirst	Provision of water
Good housing	3	Comfort around resting	Lying position, cleanliness of calves
	4	Thermal comfort	Wet calves
	5	Ease of movement	Slipperiness of the floor
Good health	6	Absence of injuries	Spots of hard skin, claw lesions, joint lesions, bursae, bitten tail/ear, lameness
	7	Absence of disease	Coughing, abnormal breathing, nasal discharge, ocular discharge, liquid manure, bloated rumen, dull calves, obviously sick calves, mortality At slaughter: lung lesions (pneumonia and pleuritis), abomasal lesions, ruminal plaque
	8	Absence of pain induced by management procedures	Routine mutilations
Appropriate behaviour	9	Expression of social behaviours	Social behaviours
	10	Expression of other behaviours	Other behaviours, abnormal behaviours
	11	Good human-animal relationship	Avoidance distance
	12	Positive emotional state	Qualitative behaviour assessment

specific problems would indeed bring a significant benefit to animals and farm economics by planning surveillance, reducing medical treatments and culling rates on one side and by improving animal performance on the other one. The importance of the risk factor analysis is therefore underlined in preventive veterinary medicine as revealed by recent literature regarding livestock categories such as dairy cattle (Somers *et al.*, 2005a; 2005b), pigs (Gillman *et al.*, 2008; 2009; KilBride *et al.*, 2009), laying hens (Van Hoorebeke *et al.*, 2009) and veal calves (Bähler *et al.*, 2009) but also working horses (Burn *et al.*, 2009) and others.

CROSS-SECTIONAL STUDY

FARM SAMPLE

The sample was chosen on the basis of the producers/farmers willing to participate in the three major veal calves producing countries of the European Union. In the Netherlands 150 farms (100 White veal and 50 Rosé veal) were randomly chosen among a wider sample of farms that reflected a correct proportion between farms belonging to integrators or private and over the veterinary practices spread in the country. In France, 50 farms were randomly selected across 4 veal producing integrators. The choice of farms was made so that the proportion of the different rearing conditions was similar to the real proportion at national level. This last approach was adopted also for the choice of the 24 farms in Italy were veal production is mainly concentrated in 3 northern regions and predominant housing is small groups (21/24). In all the three countries the farm was included in the cross-sectional study if having a batch of more than 300 calves (100 calves in Italy and 40 calves for Rosé production since batches are smaller) starting the rearing cycle on a calendar week in accordance with the research outset schedule.

RISK FACTORS

As a definition, a risk factor is a variable associated with an increased hazard of disease or infection and has the potential to cause an adverse effect. It can either be a factor such as the level of air ammonia or the need of an animal that is not fulfilled. A list of potential risk factors that are assumed to be still present in the modern conventional veal calves rearing units has been reviewed in Chapter 2.

Within Welfare Quality®, a questionnaire was drown up in order to obtain as much valid information as possible from the animal caretaker in a short time period, without need of manual or instrumental measures by the assessor. Specific data regarding veal calves management, housing and resources were indeed collected from the interview to the farmer/stockperson carried out before the first visit (Table 3.3). At the same time data regarding the type of milk delivery system, and water provision were recorded while amounts of milk-powder and amounts and prevalent type of solid feed delivered to calves in total were obtained from the farmers/industry at the end of the rearing cycle.

Duration of the rearing cycle was calculated as distance from the week of slaughter and the week of arrival (<24, 24≤x≤30; >30 wks). Environmental luminosity was evaluated objectively at about 16 wks of rearing on a three point scale (light, half-light, dark) in 20 randomly chosen pens of the same barn obtaining then a score per barn (Table 3.3). Moreover, during the rearing cycle, white veal calves were submitted to haemoglobin check bleedings and willing farmers/industry provided data from blood analysis carried out at specialized approved centers (Table 3.3).

Table 3.3 List of the tested potential risk factors for the occurrence of health problems at the digestive system in veal calves farms.

	Name	Class
Production and housing system	Type of veal meat production system	White | Rosé
	Housing system during rearing and fattening	Small (≤15 calves/pen) | Large group (>15 calves/pen)
	Farm size	≤300 | 300<x≤600 | 600<x≤1200 | >1200 n. calves total
	Space allowance	≤1.8 | >1.8 m^2/calf
	Type of floor	Slatted wooden floor | Concrete | Rubber or straw
	Estimated luminosity of the barn	Light | Half-light | Dark
	Presence of a specific sickbay	No | Yes
	Environmental enrichment	No | Yes
	Access to outdoor alley	No | Yes
	Separated lying area	No | Yes | Partly (during a period or for part of calves)
	Renovation	≤4 | 4<x≤8 | >8 years
	Floor age	≤4 | 4<x≤8 | >8 years
	Ventilation	Natural | Dynamic | Both
	Ridge (exit of air from roof)	No | Yes | Both
	Manure	Under the calves | Scraped outside
Batch characteristics	Quality of the batch at arrival	Good | Average | Bad
	Season at housing	Spring | Summer | Autumn | Winter
	Calves origin	National | Foreign | More countries
	Prevalent breed	Holstein | Dual purpose breed | Crossbred
	Percent of females	0 | 0<x≤5 | >5 %
	Estimated weight at arrival	≤43 | 43<x≤47 | 47<x≤51 | >51kg
	Average haemoglobin level at 3 and 13 weeks of rearing	≤5.7 | 5.7<x≤6.2 | >6.2 mmol/l
	Average number of calves/pen at each clinical/health visit	≤6 | 7≤x≤9 |10≤x≤15 | >15
	Duration of rearing cycle	Short (<24 wks) | Mid-term (24≤x≤30 wks) | Long (>30 wks)
Management and farmer experience	Prophylaxis treatment	No | Yes
	Use of individual baby-boxes	No | Yes
	Duration of baby-boxes use	0 | 0<x≤4 | 4<x≤6 | >6 weeks
	Use of heating	No | Yes
	Sorting/regrouping practice	No | Yes
	Cleaning for all-in/all-out	Everything | Partial | Brush only | No cleaning
	Frequency of visits by technician	Weekly | Every 2 weeks | More than 2 weeks between visits
	Frequency of visits by veterinarian/cycle	<3 | ≥3
	Frequency of visits by farmer/day	≤2 | >2
	Years of farmers' experience	≤5 | 5<x≤15 | 15<x≤25 | >25 years
	Years of adoption of the present system	≤2 | 2<x≤10 | >10 years
Feeding system	Type of milk delivery system	Bucket | Trough | Automatic Milk delivery Device (AMD)
	Total amount of milk-powder	≤280 | 280<x≤330 | 330<x≤380 | >380 kg/head/cycle
	Calves always received ≥14 liquid meals/week	No | Yes
	Prevalent type of solid feed	Maize silage | Pellets or mixture | Cereal grain[1] | Treated maize[2] | Formulation for Rosé veal[3]
	Total amount of solid feed	≤50 | 50<x≤100 | 100<x≤150 | 150<x≤300 | >300 kg DM/head/cycle
	Water provision	*Ad libitum* | Limited | No water

[1]barley or maize;
[2]dehydrated and flattened maize;
[3]prevalent component was not specified since diets contained different amounts of maize silage, pellets and straw

ON-FARM EXAMINATION

The welfare assessment protocol consisted of three clinical/health visits carried out by one trained veterinarian per farm. The visits were planned at an early phase (1st visit), early-middle (2nd visit) and end stage (3rd visit). They were carried out respectively at about 3 (2 - 6) wks after the arrival of the calves at the fattening unit, at nearly 13 (11 - 17) wks of rearing, and at the end of the rearing cycle at about 2 (1 - 4) wks prior to slaughter (Figure 3.1).

Variability in scheduling were due to different availability of assessors; to avoid overlapping with haemoglobin check bleedings or with other farm practices carried out the same week; or to postponed or anticipated slaughtering (3rd visit).

Figure 3.1 Schematic design of a veal calves' fattening cycle from housing to slaughter and the time schedule of the three on-farm clinical/health visits carried out by veterinarians during the cohort study.

The veterinarian visually assessed every individual calf of the batch (max 300 for batches larger than 200 calves) standing in the feeding alley outside of the pens if calves were housed in small groups or inside the pen if they were housed in large groups. At each visit the assessor recorded the number of calves showing signs of digestive disorders and of involvement of the respiratory system (Table 3.4 and Figures 3.2, 3.3 and 3.4).

Table 3.4 Description of the clinical/health measures regarding involvement of the veal calves' digestive and respiratory system (Welfare Quality®, 2009).

Animal measure	Description
Digestive system involvement	
Poorer body condition	Calf behind for average weight and condition for 15-30% and for more than 30% compared to the mid-range of the batch within the same breed (Figure 3.2)
Bloated rumen	Calf with obviously tensed abdomen, more convex than the shape of the ribs (Figure 3.3)
Respiratory system involvement	
Abnormal breathing (dyspnea)	Calf with tachypneic breathing (frequency higher than 40 breaths/min), excessive abdominal breathing, breathing in a pumping way, excessive nostril movement, generally sick attitude (Figure 3.4)
Nasal discharge	Visible flow/discharge from nostrils; transparent watery to yellow/green often with thicker consistency (purulent); visible because the calf does not clean its muzzle (Figure 3.4)
Coughing	Calf observed having an audible expulsion of air through the mouth

Figure 3.2 Veal calves with normal body condition and with poorer body condition for 15-30% and for more than 30% behind the mid-range of the batch (from left to right).

Figure 3.3 Veal calf with bloated rumen.

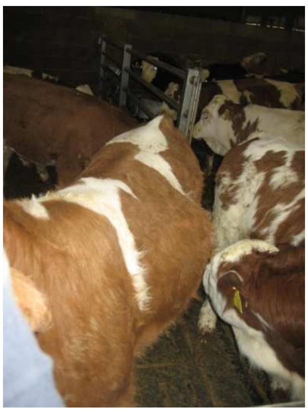


Figure 3.4 Veal calf with respiratory syndrome.

POST-MORTEM INSPECTION

A sample of calves belonging to each of the batches part of the *in vivo* cohort study were randomly chosen in accordance of slaughtering schedule and observer availability with the aim of assessing 60 rumens, 60 abomasa and 100 lungs per farm. Farms in the Netherlands conveyed all animals in 8 veal slaughterhouses, in France in 2, while in Italy smaller batches were slaughtered in different abattoirs (14) so the sampling was based on the one day when the maximum possible number of calves was planned to leave for the same slaughter.

At the time of slaughter a trained observer examined organs following track of the test batch not of individual animals within the batch. Directly at the slaughter line, before the veterinary routine inspection, the assessor visually and manually examined each lung evaluating signs of pneumonia (atelectasis, not acute fibrinous pneumonia). Normal sound lung of a pale orange colour were graded 0 = absence of pneumonia while an increasing score from 1 to 3 was attributed to lungs with signs of minimal, mild/moderate and severe pneumonia (Table 3.5). Moreover, the presence of pleuritis was also recorded as a binary measure (yes/no) for each lung (Table 3.5).

Rumen was evaluated after opening and rinsing the organ in water. An increasing score from 1 for low to 4 for fully developed rumens was given according to the description in Table 3.6. Presence (yes/no) of plaques on the rumen wall or of papillary epithelial hyperkeratinisation was also recorded for each rumen (Table 3.6).

Abomasa were evaluated in the last 15 cm of the pyloric area that was opened by a longitudinal cut. Presence of any kind of lesion at the mucosa (from erosion to open ulcer) was recorded as a binary measure (yes/no) at the pyloric area level and at the torus pylorus level. Lesions in the pyloric area (Table 3.7) were also counted (from 0 = absence of lesions to a censored maximum of 4 = presence of 4 or more lesions) according to their size class: 1 for lesions having a diameter smaller than 0.5 cm^2, 2 for lesions with size between 0.5 and 1 cm^2, and 3 for lesions larger than 1 cm^2 (Welfare Quality®, 2009).

DATA PROCESSING AND STATISTICAL ANALYSIS

Rough data obtained from the on-farm clinical/heath visits were transformed into percentages of calves showing signs of clinical/health problems over the total number of calves observed each time per farm. Data obtained during *post-mortem* inspection at the slaughterhouse were expressed as percentages of organs with a given score (i.e. % rumens with development from 1 to 4) or with a certain problem (i.e. % lungs with pleuritis or % of abomasa with at least one lesion on torus pylorus) over the total number of organs examined. A cumulative percentage of lungs with pneumonia (different from 0) was calculated, as well as a mean score per farm for rumen development (mean of the scores attributed to all the rumens observed per farm) and for abomasal lesions. The mean abomasal lesions score was weighted = [(n. of lesions size 1 x 1) + (n. of lesions size 2 x 2) + (n. of lesions size 3 x 3)] therefore it ranged from 0 for no lesions to a censored maximum of 24.

All calculations and statistical analyses were performed in GenStat (GenStat Committee, 2000) using a suite of programs that were developed for the Welfare Quality® project, having farm as experimental unit. After descriptive analysis, a stepwise approach was adopted for the building of the ultimate risk factor model. The search for potential risk factors is equivalent to subset selection of explanatory variables in regression. The response variable was one of the animal measurements, the explanatory variables were the potential risk factors reported in Table 3.3. Levels of factors were defined according to the frequency of farms per each level (HISTO procedure) and accordingly covariates were transformed into factors. Response variables that showed hardly any variation were omitted from the analysis. Each animal measurement was analysed separately and the risk factor analysis was carried out only for problems that showed an average prevalence higher than 5% (Gillman *et al*., 2009). Among groups of problems risk analysis was performed on the mostly correlated variable with the others (Spearman rank $r \geq |0.40|$, $P<0.05$) or the more relevant according to literature.

Prior to subset selection, potential risk factors were inspected individually, in univariate analyses, and in pairs. The factors that were associated with the dependent animal measurement ($P<0.10$) were examined further in a multivariate analysis. The inspection of pairs of factors offered a first impression of possible collinearities, with complete confounding as an extreme case. In case of qualitative risk factors, a check was performed for sparseness in the numbers of observations of combinations of risk factors. Variable selection was performed both by stepwise backward selection and stepwise

Table 3.5 Description of grading for lungs with signs of pneumonia (0=lung with no lesion) and presence of pleuritis (Welfare Quality®, 2009).

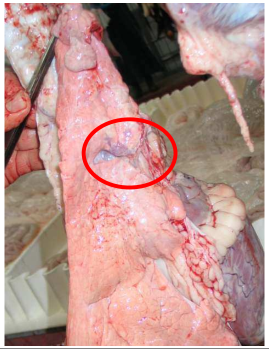
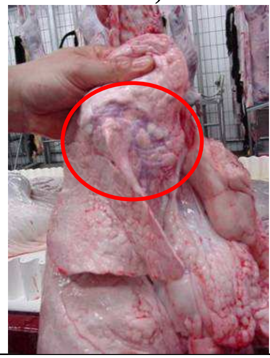
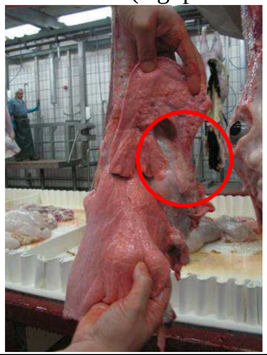
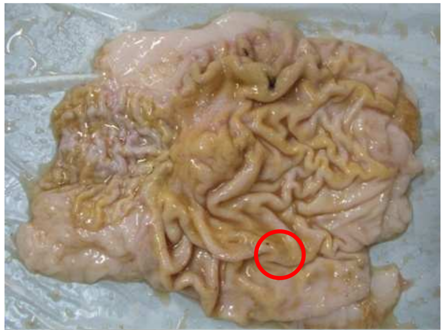
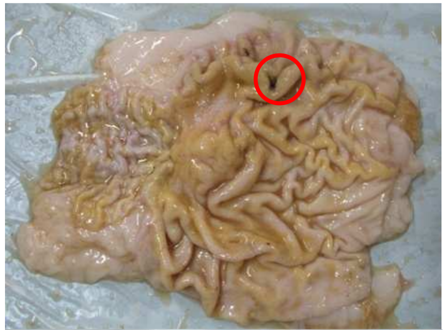
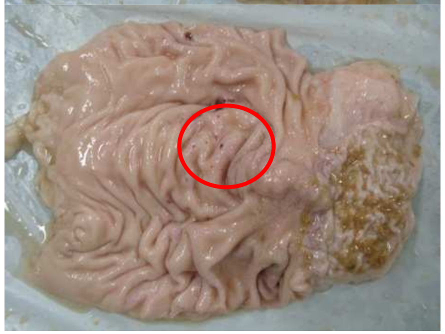
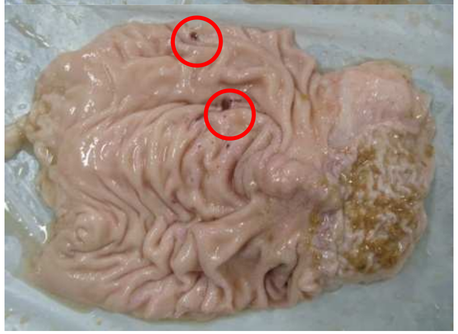
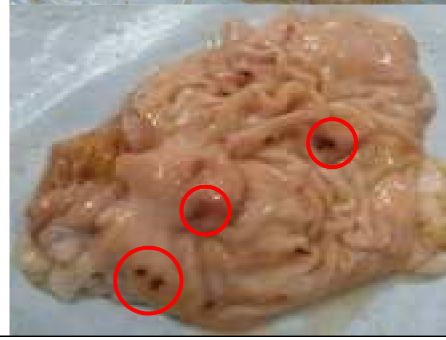
	Pneumonia				Pleuritis
	0 : no	1: minimal	2 : mild/moderate	3 : severe	Presence (yes/no)
Description	normal pale orange colour	1 spot of grey-red discoloration	1 larger or several small spots of grey-red discoloration (less than 1 lobe)	grey-red discoloration area (at least one full lobe) and/or presence of abscesses	involvement of the pleura, fibrinous attachment that connect lung lobes together or to other tissues (e.g. pericardia)
Illustration					

Table 3.6 Description of the categories of rumen development (scores from 1 to 4) and presence on the rumen of plaques (Welfare Quality®, 2009) and hyperkeratinization.

	Rumen development score			
	1 : low development	2 : moderate development	3 : well developed	4 : fully developed
Description	few papillae: nearly no papillae in atrium and in ventral and dorsal rumen	few papillae in ventral and dorsal rumen, rumen wall still visible	moderate number of papillae in ventral and dorsal rumen, rumen wall still visible, numerous papillae in atrium	numerous papillae in ventral and dorsal rumen and atrium, papillae in atrium leaflet shaped
Illustration				

	Presence on rumen (yes/no)	
	Plaques	Hyperkeratinization
Description	multiple superficial patches attached on ruminal mucosa	papillae of thicker and harder texture (visually hyperkeratinization of the epithelium looks like thickened and clustered papillae of more rounded shape/at physical contact the tissue is harder)
Illustration		

Table 3.7 Grading description of the lesions at the abomasums according to their size and number. The number of lesions ranged from 0 = absence of lesions to a censored maximum of 4 = presence of 4 or more lesions per each size class (Welfare Quality®, 2009).

		Abomasums lesions		
	Size	1 : < 0,5 cm^2	2 : 0,5 to 1 cm^2	3 : > 1cm^2
Number	1			
	2 and more			

forward selection. On the union of the final models of both selection procedures, best subset selection was performed and significance tests for the effects or coefficients of the selected risk factors were evaluated. Only risk factors that added significance to the model were retained adopting a retrospective approach. Variance inflation factors (VIFs) were evaluated, both in the preliminary inspection of pairs of risk factors and in the forward and backward selection procedures. VIFs are commonly used for quantitative risk factors as indicators for potential multicollinearity problems. We found that VIFs for dummy variables for qualitative risk factors often were useful indicators as well. VIFs were inspected in the next analyses as well. Each omitted risk factor was added in turn to the model and this factor was checked for significance. It was also checked whether the introduction of a previously omitted factor affected other factors in terms of their estimated effects or coefficients, as well as standard errors and statistical significance. A selected variable was changed for another variable, which made biologically more sense, when this involved a minor reduction of the fit of the model. For continuous variables, a linear regression model was used. For 0-1 data, fractions or percentages, a logistic regression model was used, specifying a binomial variance function with a multiplicative dispersion factor. For count data a log linear model was used, specifying a Poisson variance function with a multiplicative dispersion factor. Estimation was by quasi-likelihood. The dispersion factor in the variance was estimated from the data (McCullagh and Nelder, 1984). The criterion in backward and forward selection was the adjusted R^2. Significance tests were based on the quasi-likelihood ratio test.

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Chapter 4

RISK FACTORS FOR HEALTH PROBLEMS RELATED TO THE RESPIRATORY SYSTEM OF VEAL CALVES

RISK FACTORS FOR HEALTH PROBLEMS RELATED TO THE RESPIRATORY SYSTEM OF VEAL CALVES

Marta Brščić[1], Hélène Leruste[2], Leonie Heutinck[3], Eddy A.M. Bokkers[4], Maaike Wolthuis-Fillerup[3], Norbert Stockhofe[3], Giulio Cozzi[1], Flaviana Gottardo[1], Cornelis G. Van Reenen[3]

[1]Dipartimento di Scienze Animali. Università degli Studi di Padova, Italy
[2] Institut supérieur d'agriculture (ISA), Lille, France
[3] Animal Sciences Group of Wageningen UR, Lelystad, the Netherlands
[4]Animal Production Systems, Wageningen UR, the Netherlands

INTRODUCTION

Respiratory disorders in calves are of a relevant interest both from the theoretical (pathology) and the practical (on-farm incidence and economic loss) point of view. Infectious diseases are by far prevalent to non-infectious respiratory disorders particularly under intensive farming conditions, Bovine respiratory disease complex is a main health problem (Virtala *et al*., 1999; Assié *et al*., 2004; Autio *et al*., 2007). Etiology is attributable to multifactorial causes with a significant involvement of microbiological agents (bacteria, virus, mycoplasma) as initiating pathogens, or as exacerbating and complicating factors in synergy with other aspects (Virtala *et al*., 1999; Assié *et al*., 2004; Arcangioli *et al*., 2008; Radaelli *et al*., 2008). Predisposing and causative factors are equally important since the continuous intake and oxygen/carbon dioxide exchange between the animal organism and the environment make the respiratory system constantly exposed to the farm micro-climatic conditions. Among the extrinsic risk factors for calves respiratory-system health reported in literature, some relevant examples are the indoor housing (lack of outdoor access), insufficient space allowance, overcrowded pens, unsuitable air temperature or its quick changes, high humidity, presence of dust in the air, low oxygen levels, high ammonia concentration and others (Lungborg *et al*., 2005). Farm micro-climate and environment should therefore be appropriate to give calves a suitable aerial and thermal comfort (Cozzi *et al*., 2009).

Intrinsic predisposing factors are linked to animal immunity. A causative issue for veal calves, in particular, is that they are considered a dairy by-product so they are early separated from their dams, gathered from different farms and transported to a specialized fattening unit when they are about 10 days of age. Mixing of calves from different farms (during collection, transport and housing) exposes them to a heavy infection load also to micro-organisms to which they do not have colostral antibodies (Autio *et al*., 2007). Traditionally calves were housed in individual crates as a measure to minimize calf-to-calf contact for disease prevention. Nowadays, the adoption of group housing according to the EU regulation (European Council Directive 91/629/EC and Directive 97/2 EC) has the all-in all-out system as preventive measure in white veal farms. It is a biosecurity strategy addressed to the control of infectious disease according to which, housing chambers have to be emptied of all the animals, cleaned and disinfected before the restocking of a new batch. An additional preventive measure in small group housing is the use of individual separators during the first 8 weeks of rearing to prevent cross-sucking and respiratory problems, similarly to dairy calves (Virtala *et al*., 1999). However, repeated regrouping, a practice carried out in order to homogenise the growth of the pen-mates in those farms where the feed delivery systems allow competition is another situation that may facilitate microbes spreading among calves.

A systematic herd investigation strategy to identify prevalence of the respiratory problems should be a puller of an animal welfare assessment scheme. Its development should be based on the essential understanding of the risk factors that affect them. Once predisposing causes are recognized, the development of accurate plans, recommendations and treatments for disease prevention and management are more effective. Calf exposure to the problem source could therefore be limited and/or its immunity could be enhanced (McGuirk, 2008). As stated by the same Author a regular screening or examinations done at strategic time points improves detection of disease, monitors treatment outcomes, and it could avoid disease outbreaks.

Several studies have investigated the incidence of respiratory disease in North America and in Europe in non-weaned calves focusing mainly on dairy calves (Sivula *et al*., 1996; Virtala *et al*., 1996; 1999; Assié *et al*., 2004) and beef cattle young stock (Thomas *et al*., 2002; Hägglund *et al*., 2007). Their main aim was identifying the occurrence of the microbial pathogens through bacteriological and serological surveys. Incidence and etiology were also goals of the studies carried out on meat producing dairy calves (Assié *et al*., 2004; Arcangioli *et al*., 2008; Autio *et al*., 2007). It was aim of the current study therefore to investigate, through the cross-sectional study described in Chapter 3, the prevalence of respiratory disorders in veal calves in three following phases of their rearing cycle and at slaughter. Moreover, we aimed at examining variation among the two types of production system (White veal calves and Rosé veal calves) and at analysing the relevant risk factors for the occurrence of problems at the respiratory system.

RESULTS

DATA ON FARM AND MANAGERIAL CHARACTERISTICS

Reflecting the European veal calves production, the majority of farms (146) included in the sample raised the conventional white veal in groups smaller than 10 calves/pen. Fifty farms adopted the type of production for Rosé veal, either in small (38) and large groups moving calves according to different stages of the rearing cycle. The cross-sectional study covered the entire year having a normal distribution of farms starting the rearing cycle across the four seasons.

Most of the farms reared Holstein calves (67% of the White and 96% of the Rosé veal farms) either national or imported. Calves were prevalently males since 154 batches included less than 5% of females. The farm size, expressed as average number of calves present in total at the farm at the moment of the interview to the farmer was 748.8±664.8 (mean±SD) going from a minimum of 62 to a maximum of 5800. The test batch size at the beginning of the cohort study was of an average of 226.1±91.3 calves (252 in White and 133 in Rosé veal farms) housed in 40.4±18.4 pens.

The space allowance per calf was in accordance with the legal requirements, and only in a low percent of farms (21% of White and 28% of Rosé farms) it was higher that the indication of 1.8 m^2/calf for the entire duration of the rearing cycle. The duration of the fattening cycle differed between the two types of meat production systems lasting less than 30 wks for all White veal units but one and reaching the maximum of 43 wks in the Rosé production. The practice of regrouping calves was done in the large majority of farms (94% of the White and 98% of the Rosé farms). The use of individual baby-boxes at the early stage of the rearing cycle for up to a maximum of 8 wks was adopted for a large number of farms as well (83% of the White and 64% of the Rosé farms). Animals had the free excess to an outdoor alley in only 1 farm rearing Rosé calves.

A detailed description of the feeding strategies adopted by the two veal production systems has been presented and discussed in Chapter 5.

PREVALENCE OF RESPIRATORY DISORDERS RECORDED DURING ON-FARM OBSERVATIONS AND AT *POST-MORTEM* INSPECTION

Prevalence of clinical/health problems related to the respiratory system recorded during the application of the welfare monitoring scheme at the farm level are shown in Table 4.1.

The mean percent of calves with abnormal breathing always remained below 5%, while the calves observed coughing were 5% at the first and second visit and under that percentage at the end stage of fattening. Nasal discharge involved more than 6.2% and 6.5% of calves at the first and third visit respectively reaching a maximum prevalence of 45% in one farm.

In regard to the *post-mortem* inspection a mean number of 128 lungs with a standard deviation of 60.4 was observed in 209 farms (15 missing values). On average 52.4% of lungs were involved by at least a spot of grey-red discoloration as sign of minimal pneumonia (lungs with scores different from 0) ranging from a minimum of 0 to a maximum of 91.7%. As shown in a schematic way in Figure 4.1, 29% of lungs showed minimal signs of pneumonia while the worse condition interested 9% of lungs. Pleuritis involved 25.1% of lungs with a median of 23 and a range from 0 to 97.9%.

Type of veal meat production system did not show significant differences regarding nasal discharge prevalence at any of the three observation sessions (P>0.05) while all of the *post-mortem* measurements except for the percentage of lungs that showed minimal signs of pneumonia were significantly different between the two systems (Table 4.2). Rosé veal showed a worse situation regarding lung lesions with a higher prevalence of moderate and severe signs of pneumonia and of pleuritis.

Table 4.1 Respiratory problems prevalence (% of calves interested by a given problem/calves observed) in three different stages of the fattening cycle in 221 veal calves farms.

Observation		Animal measure	Unit	Mean	SE	Coef. of variation	Min	Max
On farm	3 weeks after housing	N. of calves observed	mean	226.1	6.14	40.4	37	432
		Abnormal breathing	% calves	3.6	0.31	129.1	0	28.0
		Nasal discharge	”	6.2	0.43	102.6	0	31.0
		Coughing	”	5.0	0.27	80.1	0	22.0
	13 weeks after housing	N. of calves observed	mean	225.9	6.09	40.2	37	427
		Abnormal breathing	% calves	1.4	0.12	120.8	0	10.3
		Nasal discharge	”	4.8	0.38	117.4	0	33.8
		Coughing	”	5.0	0.29	87.5	0	25.0
	2 weeks before slaughter	N. of calves observed	mean	221.5	6.04	40.6	35	422
		Abnormal breathing	% calves	0.6	0.08	196.0	0	10.3
		Nasal discharge	”	6.5	0.53	121.9	0	45.0
		Coughing	”	4.0	0.30	112.0	0	39.1

Figure 4.1 Lung lesion prevalence in veal calves at batch level.

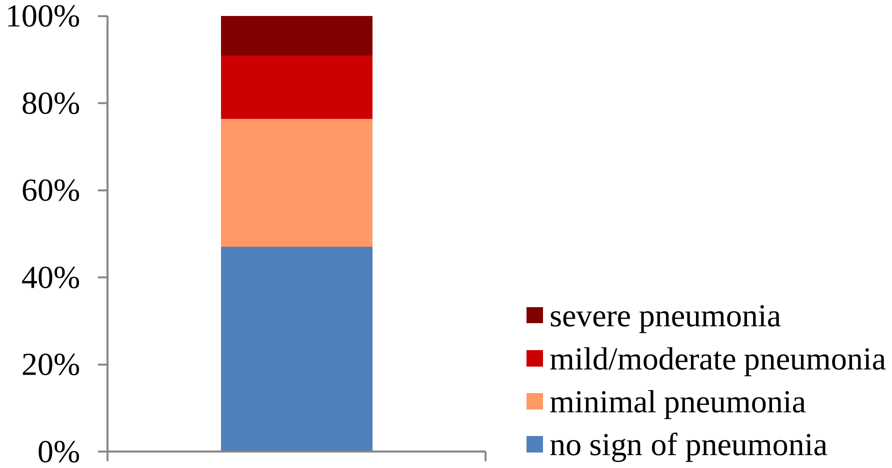

Table 4.2 Results from measurements carried out at the slaughterhouse on lungs and pleura according to the type of meat production system (White vs. Rosé).

Item	Unit	Type of meat production system				*P*
		White		Rosé		
		lsmean	SE	lsmean	SE	
Lung with signs of pneumonia						
absence (no sign)	% lungs	48.88	1.31	36.83	2.67	***
minimal	”	28.79	0.08	30.13	0.17	ns
mild/moderate	”	13.70	0.58	17.73	1.36	**
severe	”	7.58	0.58	15.17	1.65	***
Lung with pneumonia (≠ 0)		50.07	1.32	63.03	2.71	***
Mean pneumonia[1]	score 0-3	0.80	0.03	1.11	0.06	***
Pleuritis	% lungs	21.33	1.62	41.92	2.97	***

ns = non significant; ** = *P*<0.01; *** = *P*<0.001

[1]= score calculated as mean of the scores of all the graded lungs per batch (from 0 to 3)

RISK FACTOR ANALYSIS

Risk factor analysis for respiratory problems identified during clinical/health visits

The prevalence of nasal discharge was above 6% at the first and third visit therefore further analysis was performed for this variable considering potential risk factors in all three stages of the rearing cycle. Spearman rank correlation showed that nasal discharge was significantly (P<0.05) correlated to both, abnormal breathing and coughing at all three visits. Risk factor analysis for nasal discharge recorded during the 1st visit was carried out considering data of both types of veal meat production systems since at 3 weeks after arrival at the fattening unit, both White and Rosé veal calves were basically kept in the same manner in terms of housing and diet and were, therefore, exposed to the same risk factors. Since there were relevant differences between the two production systems related to housing conditions and to feeding strategies from the second visit on, the risk factor analysis was further on restricted to White veal only.

From the one-way analysis it resulted that most of the significant risk factors for the occurrence of nasal discharge acted in the same way, particularly in regard to the first 2 stages of the fattening cycle (results not shown). The effect of the use of a prophylactic treatment at the outset of the cycle was not relevant at any stage. Levels of comparison of risk factors that showed an OR over 1 for nasal discharge throughout the entire rearing cycle were the national origin of calves, and a frequency of visits by the veterinarian lower than 3/cycle; while protective factors were the manure kept under the calves for the duration of the fattening (not scraped outside), a percentage of females in the batches below or equal to 5, an estimated weight at arrival at the farm lighter or equal to 43 kg, and a space allowance equal or lower than 1.8 m^2/calf. Animals housed in small farms, with a rearing capacity of less than 300 calves in total, had an increased risk of having a nasal discharge at the first and second visit compared to those in large farms. At both 3 and 13 wks after housing dynamic ventilation was a risk factor: at 3 weeks it was a risk compared to farms that had both natural and dynamic ventilation while at 13 weeks natural ventilation was a protective factor in comparison to dynamic. An OR over 1 was found for the same dependent variables when calves had an average haemoglobin level below 5.7 mmol/l at the 3-week check compared to batches where it ranged between 5.7 and 6.2.

Factors highly associated (P<0.001) with the risk of occurrence of nasal discharge in veal calves at the early stage of rearing were space allowance and type of housing system, included in the multivariate logistic regression model presented in Table 4.3. Animals housed with a smaller space allowance seemed having a lower risk of occurrence of nasal discharge compared to those with a space larger than 1.8 m^2/calf. Small group housing was a protective factor with an OR of 0.49 compared to the adoption of large groups.

Table 4.3 Multivariate regression model for occurrence of nasal discharge in veal calves at 3 weeks after housing.

Risk factor	Level of comparison I	Level of comparison II	OR	95% CI		*t* pairwise comparison
				lower	upper	
Space allowance (m²/calf)	≤1.8	>1.8	0.54	0.41	0.70	***
Housing system during rearing	Small	Large	0.49	0.37	0.66	***

*** = t<0.001
Model considers Housing system during rearing and Space allowance; Adjusted R^2=21.93%
All factors in the model were significant for P<0.001

Risk factors that were mostly associated to occurrence of nasal discharge at 13 weeks after housing in White veal calves were duration of the use of individual separators, the prevalent type of solid feed, type of milk delivery system, the extent of adoption of the present system in years and the season at housing (Table 4.4). The final multivariate risk factor model reported in Table 4.6, indeed, explained 38.6% of the variability within farms rearing White veal. Not adopting baby-boxes (equivalent to 0 weeks) compared to duration of permanence in baby-boxes for 4 to 6 weeks and above 6 showed an OR below 1. A short duration of individual separators use (0<x≤4) also resulted being a protective factor when compared to a longer permanence of calves in such housing conditions. Pairwise comparisons showed that calves that were fed pellets/mixture had a lower risk of having a visible flow from the nostrils than those receiving cereal grain or treated maize as prevalent type of solid feed. Years of adoption of the present system was a factor that had classes always showing OR higher than 1. The implementation of individual buckets for the milk delivery seemed increasing for two times the risk of nasal discharge occurrence in comparison to the use of the common troughs. An odds ratio over 2 was observed also when calves were housed in Autumn compared to Winter, while housing animals during Spring could be considered a protective factor.

Table 4.4 Multivariate regression model for occurrence of nasal discharge in White veal calves at 13 weeks after housing.

Risk factor	Level of comparison I	Level of comparison II	OR	95% CI lower	95% CI upper	*t* pairwise comparison
Duration of baby-boxes use (weeks)	0	0<x≤4	0.42	0.15	1.21	ns
	0	4<x≤6	0.25	0.09	0.67	**
	0	>6	0.22	0.08	0.57	**
	0<x≤4	4<x≤6	0.60	0.36	0.99	*
	0<x≤4	>6	0.52	0.28	0.94	*
	4<x≤6	>6	0.87	0.59	1.28	ns
Prevalent type of solid feed	Maize silage	Pellets or mixture	1.46	0.85	2.51	ns
	Maize silage	Cereal grain	0.69	0.45	1.06	ns
	Maize silage	Treated maize	0.82	0.42	1.61	ns
	Pellets or mixture	Cereal grain	0.47	0.29	0.78	**
	Pellets or mixture	Treated maize	0.56	0.36	0.88	*
	Cereal grain	Treated maize	1.19	0.63	2.23	ns
Years of adoption of the present system	≤2	2<x≤10	1.61	1.06	2.44	*
	≤2	>10	3.18	1.65	6.14	**
	2<x≤10	>10	1.98	1.15	3.40	*
Type of milk delivery system	Bucket	Trough	2.33	1.31	4.16	**
	Bucket	AMD	1.13	0.32	3.99	ns
	Trough	AMD	0.49	0.13	1.82	ns
Season at housing	Spring	Summer	0.49	0.31	0.77	**
	Spring	Autumn	0.39	0.24	0.65	***
	Spring	Winter	0.90	0.44	1.82	ns
	Summer	Autumn	0.81	0.54	1.21	ns
	Summer	Winter	1.83	0.96	3.49	ns
	Autumn	Winter	2.27	1.26	4.12	**

ns = non significant; * = t<0.05; ** = t<0.01;*** = t<0.001
Model considers Duration of baby-boxes use, Prevalent type of solid feed, Years of adoption of the present system, Type of milk delivery system and Season at housing; Adjusted R^2=38.64%
All factors in the model were significant for P<0.05

In addition to the risk factors significant in the univariate analysis (some already mentioned above for the occurrence of nasal discharge throughout the entire fattening cycle) highly linked factors at 2 weeks before slaughter were the quality of the batch at arrival, the farm size in terms of the total number of calves present at the farm, the duration of the rearing cycle, the type of ventilation and the presence of a ridge on the roof that allows exit of air (Table 4.5). Unexpectedly, batches that were described by the farmer as of a good quality at the beginning of the rearing showed an increased risk of nasal discharge at the end. Small farms that reared a maximum of 300 calves in total showed an OR of 1.97 compared to slightly bigger farms housing from 300 to 600 calves. Farms of this size seemed having the lowest prevalence of nasal discharge. A short fattening cycle also increased the risk of nasal discharge at 2 weeks before slaughter. On the contrary natural ventilation and absence of a ridge decreased such risk.

Table 4.5 Multivariate regression model for occurrence of nasal discharge in White veal calves 2 weeks before slaughter.

Risk factor	Level of comparison I	Level of comparison II	OR	95% CI lower	95% CI upper	*t* pairwise comparison
Quality of the batch at arrival	Good	Average	1.73	1.16	2.57	**
	Good	Bad	0.92	0.48	1.78	ns
	Average	Bad	0.53	0.26	1.11	ns
Farm size (n. calves present in total)	≤300	300<x≤600	1.97	1.18	3.27	*
	≤300	600<x≤1200	1.00	0.59	1.70	ns
	≤300	>1200	0.83	0.43	1.60	ns
	300<x≤600	600<x≤1200	0.51	0.31	0.83	**
	300<x≤600	>1200	0.42	0.23	0.77	**
	600<x≤1200	>1200	0.83	0.50	1.39	ns
Duration of the rearing cycle (weeks)	Short (<24)	Mid-term (24≤x≤30)	4.17	2.61	6.66	***
	Short (<24)	Long (>30)	8.60	0.04	1959.42	ns
	Mid-term (24≤x≤30)	Long (>30)	2.06	0.01	469.78	ns
Ventilation	Natural	Dynamic	0.26	0.13	0.51	***
	Natural	Both	0.37	0.17	0.82	*
	Dynamic	Both	1.44	0.76	2.73	ns
Ridge	No	Yes	0.48	0.29	0.77	**
	No	Both	0.54	0.26	1.13	ns
	Yes	Both	1.14	0.55	2.37	ns

ns = non significant; * = $t<0.05$; ** = $t<0.01$;*** = $t<0.001$
Model considers Quality of the batch at arrival, Farm size, Duration of the rearing cycle, Ventilation and Ridge (exit of air from roof); Adjusted R^2=45.69%
All factors in the model were significant for $P<0.05$

Risk factor analysis for respiratory disorders identified during post-mortem inspection

Regarding the *post-mortem* measurements, risk factor analysis was completed on the percentage of lungs involved by at least a minimal sign of pneumonia (cumulative percentage of lungs with scores ≠0) and by pleuritis that showed both a high prevalence. The cumulative percentage of lungs involved by signs of pneumonia was significantly correlated to the other measures (r=-0.97 for % lungs score 0, r=0.53 for % lungs score 1, r= 0.75 for % lungs score 2, r=0.71 for % lungs score 3; $P<0.01$). Even though the prevalence of signs of pneumonia was higher in Rosé veal, the risk factor analysis was carried out on data regarding the White veal production system. The choice was due to absence of significant factors, among those investigated in the current study, considering Rosé veal farms. The only exception was an OR of 1.63 (95% CI = 1.05-2.53, $t<0.05$) obtained by the univariate analysis for the absence of a dedicated sickbay compared to Rosé farms that adopted such facility ($P<0.05$).

Risk factors highly linked to the occurrence of signs of pneumonia on White veal calves lungs are presented in Table 4.6. It is interesting to notice that a short term rearing cycle lasting less than 24 weeks, housing animals during the summer season, bucket feeding and new floors (aged below 4 years) increased the risk of developing at least a minimal sign of pneumonia.

Duration of the rearing cycle and water provision were the decisive risk factors for occurrence of pleuritis (Table 4.7). In particular signs of fibrinous attachments were observed in farms where water was provided *ad libitum*. On the contrary in farms that finished calves prior to 24 weeks the OR was below 1.

Table 4.6 Multivariate regression model for occurrence of at least a minimal sign of pneumonia on lungs (cumulative percentage of lungs with scores ≠0) in White veal calves.

Risk factor	Level of comparison I	Level of comparison II	OR	95% CI		*t* pairwise comparison
				lower	upper	
Duration of the rearing cycle (weeks)	Short (<24)	Mid-term (24≤x≤30)	2.98	1.64	5.43	**
	Short (<24)	Long (>30)	7.02	2.06	23.93	**
	Mid-term (24≤x≤30)	Long (>30)	2.35	0.80	6.94	ns
Season at housing	Spring	Summer	0.39	0.26	0.58	***
	Spring	Autumn	0.71	0.48	1.06	ns
	Spring	Winter	0.94	0.64	1.37	ns
	Summer	Autumn	1.83	1.39	2.41	***
	Summer	Winter	2.41	1.75	3.31	***
	Autumn	Winter	1.31	0.96	1.79	ns
Type of milk delivery system	Bucket	Trough	3.27	2.28	4.69	***
	Bucket	AMD	3.18	1.98	5.10	***
	Trough	AMD	0.97	0.69	1.38	ns
Age of the floor (years)	≤4	4<x≤8	1.59	1.26	2.01	***
	≤4	>8	1.61	1.22	2.12	**
	4<x≤8	>8	1.01	0.78	1.31	ns

ns = non significant; ** = *t*<0.01;*** = *t*<0.001
Model considers Duration of the rearing cycle, Season at housing, Type of milk delivery system and Age of the floor; Adjusted R^2=39.80%
All factors in the model were significant for *P*<0.02

Table 4.7 Multivariate regression model for occurrence of pleuritis in White veal calves.

Risk factor	Level of comparison I	Level of comparison II	OR	95% CI		*t* pairwise comparison
				lower	upper	
Duration of the rearing cycle (weeks)	Short (<24)	Mid-term (24≤x≤30)	0.27	0.19	0.37	***
	Short (<24)	Long (>30)	0.48	0.09	2.43	ns
	Mid-term (24≤x≤30)	Long (>30)	1.78	0.36	8.87	ns
Water provision	Ad libitum	Limited	1.59	0.89	2.85	ns
	Ad libitum	No water	1.75	1.21	2.53	**
	Limited	No water	1.10	0.59	2.06	ns

ns = non significant; ** = *t*<0.01;*** = *t*<0.001
Model considers Duration of the rearing cycle and Water provision; Adjusted R^2=38.84%
All factors in the model were significant for *P*<0.001

DISCUSSION

Prevalence of clinical signs of respiratory disorders in calves observed during clinical/health observations in the current study were on average below those recorded by Nikunen *et al*., (2007) in Finland in 18 herds of fattening and dairy calves ranging from 8 to 20 weeks of age. They reported 44.1%, 78.6% and 45.2% of calves interested by increased respiratory rate, coughing and nasal discharge, respectively. Virtala *et al*., (1996) reported an incidence of 25.6% of dairy heifers with pneumonia diagnosed by a veterinarian during the first 3 months of life. *In vivo* results of the current study were comparable only to the incidence of 5.8% reported by Perez *et al*., (1990) in Dutch dairy calves herds. Prevalence of *post-mortem* signs of respiratory disorders were higher than respiratory signs recorded *in vivo* in both types of production system. Although, inspection at the slaughterhouse resulted being a useful tool to identify respiratory disorders, several relevant risk factors for occurrence of nasal discharge were found. They were related to the housing system (i.e. housing system during rearing, space allowance, type of floor and farm size), to certain managerial choices (use of individual baby-boxes, frequency of visits by the veterinarian and by the farmer), to feeding strategies (type of milk delivery system, prevalent type of solid feed and water provision) and to particular characteristics of the examined batches such as origin of calves, percent of females in the batch, estimated weight at arrival, average haemoglobin level at 3 weeks and season at housing. Same risk factors prevalently acted in the same way throughout the entire fattening cycle in regards to occurrence of nasal discharge. However, at each stage different factors were important. The finding regarding the lower risk of nasal discharge at 3 weeks when animals were housed in small groups compared to large groups is in agreement with results from Lundborg *et al*., (2005), but an explanation is missing. On the contrary the increased risk of nasal discharge at 13 weeks when animals were housed during autumn, considering that the assessment was carried out approximately the same season or the subsequent to the one at housing, could be easily associated to odd ratio of 2.46 and 1.94 for respiratory disease during autumn and winter respectively (Lundborg *et al*., 2005).

Regarding feeding systems, individual buckets increased the risk of flow from the nostrils and of *post-mortem* signs of pneumonia compared to the use of common troughs. This finding was unexpected since, due to high drinking voracity, some milk-replacer diet could be aspirated and enter by error into the airways resulting therefore in a nasal discharge and *ab ingestis* pneumonia. Drinking competition is particularly exacerbated in the common mangers and it is much lower when every calf receive an individual ration (Jensen, 2003).

The use of baby-boxes during the first 8 weeks of rearing demonstrated to be a preventive measure for occurrence of nasal discharge at the middle stage in accordance with previous findings (Virtala *et al*., 1999). Duration of the use of individual separators should however be short ranging from 1 to 4 weeks.

A particular finding was that a good quality batch at the beginning of the rearing could still present an increased occurrence of nasal discharge at the end of the cycle. This confirms that environmental and managerial choices affect the health status of calves (Waltner-Toews *et al*., 1986). Natural ventilation acted as a preventive measure mainly when compared to dynamic, as well as close barns compared to farms where air exit from the roof by a ridge. The importance of ventilation systems has been proved in several studies and in particular Hillman *et al*. in 1992 studied a very effective ventilation system in a calf nursery that reduced airborne bacteria and dust particles by filtering the incoming air. The system permitted also control of temperature, humidity, and ammonia concentrations reducing symptoms and incidence of pneumonia. Calf to calf airborne pathogens in the study were reduced by curtains of polyethylene that likely prevented also draught. Indeed, Lundborg *et al*. (2005) reported an increased risk for respiratory sounds at lung auscultation for calves housed in farms where a draught was detected.

These considerations, associated to the negative effect of the cold season increases the hypothesis that environmental temperature is highly relevant when discussing respiratory problems. In the current study manure kept under the calves for the duration of the fattening (not scraped outside) acted as a protective factor for occurrence of nasal discharge. It is likely that manure fermentation increases environmental temperature at the calf level during the cold season even thou it increases air ammonia. While negative effects of ammonia are well known (Kiorpes *et al*., 1988), these results would confirm the controversial findings obtained by Lundborg *et al*. (2005) who observed low risk of respiratory disorders at the highest levels of ammonia. However, individual animal body temperatures should be taken into account in order to facilitate the assessment of stress response and identify ways to improve environmental management such as the reduction of exposure to high levels of ammonia, draught and non appropriate barn temperatures (Macaulay *et al*., 1995).

The effect of the use of a prophylactic treatment at the outset of the cycle was not relevant for any dependent variable in this cohort study while it is well known that preventive antibiotic treatments decrease the risk of later treatment for respiratory disease (Waltner-Toews *et al*., 1986). A relevant risk factor for occurrence of nasal discharge throughout the entire rearing cycle in the present study was a frequency of visits by the veterinarian below 3/cycle. This is likely linked to the number of pharmaceutical treatments of calves by the clinician. A further confirmation is obtained by the fact that none of the investigated potential risk factors in the present study gave significant results on the incidence of respiratory problems in the Rosé veal meat production system where the occurrence of *post-mortem* signs of pneumonia was significantly higher and worse, and the system itself claims a lower use of antibiotics. Farm books should therefore also be investigated and more research is needed concerning treatments.

CONCLUSION

Finding of the present paper confirmed the importance of evaluating signs of pneumonia both at the farm level and at the time of slaughter and of researching separately risk factors for each of the rearing phase. Differently from previous studies that focused on risks among infectious and immunological causes or gave priority to air quality when considering respiratory disorders we found several interesting risk factors for each problem. Considering however, that some risks acted in the same way further investigation should be carried out in order to assess correlations and associations between *in vivo* and *post-mortem* records.

Including investigation of risk factors in welfare assessment or in other epidemiological monitoring schemes would be a helpful tool to quantify the associations between risks of disease and animal, herd, management or environmental factors even though they should also consider farm treatments records.

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Chapter 5

RISK FACTORS RELATED TO FEEDING STRATEGIES FOR GASTROINTESTINAL DISORDERS RECORDED DURING *POST-MORTEM* INSEPCTION OF VEAL CALVES

RISK FACTORS RELATED TO FEEDING STRATEGIES FOR GASTROINTESTINAL DISORDERS RECORDED DURING *POST-MORTEM* INSEPCTION OF VEAL CALVES

Marta Bršćić[1], Norbert Stockhofe[2], Leonie Heutinck[2], Flaviana Gottardo[1], Maaike Wolthuis-Fillerup[2], Eddy A.M. Bokkers[3], Giulio Cozzi[1], Joop Lensink[4], Cornelis G. Van Reenen[2]

[1]Dipartimento di Scienze Animali. Università degli Studi di Padova, Italy
[2]Animal Sciences Group of Wageningen UR, Lelystad, the Netherlands
[3]Animal Production Systems, Wageningen UR, the Netherlands
[4]Institut supérieur d'agriculture (ISA), Lille, France

INTRODUCTION

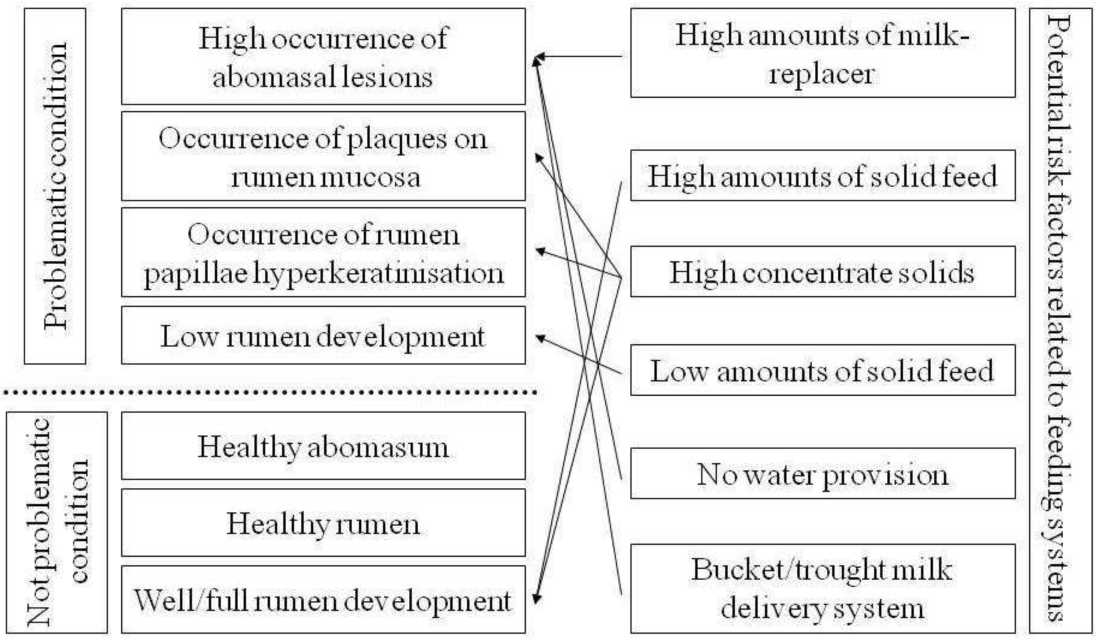
Gastrointestinal disorders in veal calves are widely described in literature. According to Wiepkema *et al*. (1987) the first findings of abomasal damage in veal calves could be dated 1912. Almost a century later abomasal lesions are still reported as a warring problem involving more than half of the veal calves population (Bähler *et al*., 2009). However, they are not the only relevant disorder since white fleshiness that characterizes this type of production system, by-product of the dairy industry, is linked to anemia and avoidance of the full development of the calf into a functioning ruminant (Tamate *et al*., 1962). Rumen development notably improved with the obligation (European Council Directives 91/629/EC and 97/2/EC) to deliver a minimum amount of solid feeds to calves in addition to the traditional all-liquid diet (Morisse *et al*., 1999, 2000, Cozzi *et al*., 2002; Suáres *et al*., 2006). However, anatomical and histological observations of ruminal epithelia of calves led to the identification of alterations such as parakeratosis (hyperkeratinisation of papillae) described in young dairy stock by Gilliland *et al*., (1962) and by Hinders and Owen (1965). Suáres *et al*. (2006) investigated also a pathological condition of the ruminal mucosa characterized by coalescing papillae with embedded hair and feed particles, defined as plaques.

Seen the main physiological function of the digestive system, preponderance of disorders and critical situations at the animal gastro-intestinal tract level occur when there are feedstuff alterations both in quantity and quality. Etiology is, however, linked to other predisposing factors or causative stressors that could contribute or lead to moderate and severe problems. Abomasal damage for example was at first associated to overloading of the stomach by the high amounts of milk-replacer diet fed at once in buckets and to roughage sources (Wiepkema *et al*., 1987). Rough, not adequately grounded fibrous materials showed to increase the incidence of abomasal damage in a mechanical way (van Putten, 1982; Wiepkema *et al*., 1987; Cozzi *et al*., 2002; Mattiello *et al*., 2002). Abnormal behaviours (stereotypies) were considered other critical points (Wiepkema *et al*., 1987). Recently, particularly the abomasal lesions in the pyloric area were associated also to risk factors different from the type of feed, type of milk replacer and feeding techniques (Bähler *et al*., 2009).

Regarding rumen development, effects of solid feeds on the digestive physiopathology of preruminant calves are well known. Indeed, despite the anatomical changes forestomach undergoes in the first 12 wks of age (Johnson, 1996), its functional development results from microbial fermentation and physical stimuli on papillae (Eadie *et al*., 1959; Gilliland *et al*., 1962; Assane and Dardillat, 1994; Beharka *et al*., 1998). Up today there are no specific legal requirements regarding type and quality of solid feeds for veal calves (European Council Directive 2008/119/EC). Consequently un uncontrolled intensive feeding regime based on high-starch/low-fibre diets or all-concentrate rations brought to ruminal mucosa alterations as ruminal hyperkeratinisation (Gilliland *et al*., 1962; Hinders and Owen, 1965) and ruminal plaques (Suáres *et al*., 2006).

White (special-fed) and Rosé (grain-fed) veal calves production systems differ particularly regarding their feeding strategies. Rosé veal production is characterized by low quantities of the milk-replacer diet and high amounts of solid feeds with no restriction of iron intake, promoting calves condition of ruminants by weaning (Report on the Welfare of Calves, 1995). It was aim of the current paper to assess, through a cross-sectional study previously described in Chapter 3, the prevalence in the three major veal meat producing countries in Europe of digestive system disorders in veal calves. Further aims were to examine variation among the two types of veal meat production and to investigate relevant risk factors present at the farm level for the occurrence of digestive problems with particular attention to the feeding system (Figure 5.1).

Figure 5.1 Schematic design of associations between problematic/non problematic conditions at the digestive system of pre-weaned calves and effects related to the feeding strategies described in literature that were considered as starting base for hypothesis formulation and risk factors investigation in the present study.



RESULTS

DATA ON FARM AND MANAGERIAL CHARACTERISTICS

Farms included in the sample reflected European veal calves production with a large majority adopting the conventional white veal rearing system in small groups and a minor part rearing calves for Rosé veal meat production. The main farm characteristics are described and categorized into levels according to the type of veal meat production system in Table 5.1.

White veal calves were all slaughtered within 30 wks of fattening with the exception of calves from 1 farm. Duration of the rearing cycle was longer in the Rosé production system reaching a maximum of 43 wks from their housing in the fattening units.

Feeding strategies varied between the two production systems and they mainly consisted of the big disparity in the type of solid feeds and the total amounts of feeds distributed to a calf during the rearing cycle. The liquid diet was distributed to White veal calves mostly in common troughs in amounts with an average of 286.9 kg of milk-replacer powder/head/cycle. The prevalent system for milk distribution in Rosé farms was individual bucket but calves received throughout the fattening cycle a smaller amount of milk-powder, on average below 30 kg/head. The opposite situation regarded solid feeds since the amounts delivered to White veal were on average 103.9 kg DM/head/cycle while Rosé veal calves received each a mean of 1130.4 kg throughout their longer fattening cycle. Water was provided *ad libitum* in all Rosé veal farms while in 33 White veal farms it was not available for calves at any stage of the rearing cycle.

PREVALENCE OF DIGESTIVE DISORDERS RECORDED DURING THE THREE CLINICAL/HEALTH VISITS

Among problems at the digestive system recorded *in vivo* during the three clinical/health visits, the average prevalence of bloated rumen showed an increasing trend during the fattening cycle but it never involved 5% or more calves of the test batch (Table 5.2). The high standard deviation at the third visit was due to outliers. Calves within the same breed with poorer body condition compared to the remaining batch-mates always remained below 4% of the total observed. The lowest prevalence was recorded particularly for the worse class of body condition which considered animals 30% or more below the mid-range of the batch.

Table 5.1 Frequency (number of farms) of the main tested potential risk factors regarding duration of the rearing cycle and housing system during fattening and different feeding strategies for the occurrence of health problems at the digestive system in veal calves farms according to the type of veal meat production system (White and Rosé).

Risk factor classes	Type of veal meat production system	
	White	Rosé
Total number of farms with post-morted data recorded	171	38
Duration of the rearing cycle		
Short	50	0
Mid-term	120	3
Long	1	35
Housing system during fattening		
Small group	149	28
Large group	22	6
Type of milk delivery system		
Bucket	45	24
Trough	103	12
AMD	25	10
Total amount of milk-powder (kg/head/cycle)		
≤280	0	36
280<x≤330	25	0
330<x≤380	62	0
>380	36	0
Calves always received ≥14 liquid meals/week		
No	23	0
Yes	143	36
Prevalent type of solid feed		
Maize silage	65	0
Pellets or mixture	61	0
Cereal grain	28	0
Treated maize	11	0
Formulation for Rosé veal[3] without by-products	0	4
Formulation for Rosé veal[3] with by-products	0	12
Formulation for Rosé veal[3] with by-products and hay/grass silage	0	6
Total amount of solid feed (kg DM/head/cycle)		
≤50	26	0
50<x≤100	35	0
100<x≤150	75	0
150<x≤300	19	0
>300	0	16
Water provision		
Ad libitum	45	38
Limited	92	0
No water	33	0

[1]barley or maize
[2]dehydrated and flattened maize
[3]prevalent component was not specified since diets contained different amounts of maize silage, pellets and straw

Table 5.2 Bloated rumen and poorer body condition prevalence (% of calves interested by a given problem/calves observed) in three different stages of the fattening cycle in 221 veal calves farms.

Observation		Animal measure	Unit	Mean	SE	Coef. of variation	Min	Max
On farm	3 weeks after housing	N. of calves observed	mean	226.1	6.14	40.4	37	432
		Bloated rumen	% calves	0.60	0.11	273.8	0	13.2
		Poorer body condition						
		15-30% behind	”	1.94	0.27	204.4	0	21.8
		>30% behind	”	0.16	0.04	375.6	0	4.0
	13 weeks after housing	N. of calves observed	mean	225.9	6.09	40.2	37	427
		Bloated rumen	% calves	2.44	0.43	260.8	0	42.3
		Poorer body condition						
		15-30% behind	”	3.26	0.22	99.1	0	18.4
		>30% behind	”	0.58	0.07	177.0	0	8.5
	2 weeks before slaughter	N. of calves observed	mean	221.5	6.04	40.6	35	422
		Bloated rumen	% calves	4.27	0.70	245.0	0	65.9
		Poorer body condition						
		15-30% behind	”	3.75	0.22	87.3	0	19.4
		>30% behind	”	0.77	0.08	147.4	0	8

PREVALENCE OF DIGESTIVE DISORDERS RECORDED DURING *POST-MORTEM* INSPECTION

Post-mortem data of fifteen farms were not available therefore the number of assessed batches was 209, respectively 138 in the Netherlands, 47 in France and 24 in Italy. One hundred seventy one farms adopted the conventional White veal production system while among Dutch farms 38 fattened Rosé veal calves (Table 5.1). The average number of observed organs was 57.3±11.2 (mean±SD) abomasa and 58.1±10.8 rumens per farm.

Regarding rumen development the prevalence of rumens with score 1, 2, 3 and 4 was on average 49.1, 23.3, 12.9 and 14.2%, respectively. Low development (score 1) had a prevalence of 60% in White veal while more than 99% of rumens belonging to calves reared in the Rosé production system fell in the well and fully developed categories (Table 5.3). Rumen plaques involved on average 25.6% of rumens in the 209 test farms but data of Table 5.3 show how this problem was almost exclusively observed in the white veal. The mean prevalence of rumens with papillae hyperkeratosis was 5.3%. Similarly 6.1% of rumens from White veal and only 1.2% from Rosé production (P<0.001) were recorded with rumen hyperkeratosis (Table 5.3).

Abomasal damage recorded at the slaughterhouse showed very high prevalence. On average 70.6% of abomasa were involved by lesions in the pyloric area and 70.7% showed a lesion on the torus pylorus. Type of veal meat production showed significant differences for prevalence of abomasal lesions in the pyloric area and on torus pylorus (P<0.001) with the highest discrepancy among White and Rosé for the latter. However, both productive systems showed a high prevalence involving at least 44% of abomasa (Table 5.3).

Table 5.3 Results from measurements carried out at the slaughterhouse on rumens and abomasa according to the type of meat production system (White vs. Rosé).

Item	Unit	Type of meat production system				*P*
		White		Rosé		
		lsmean	SE	lsmean	SE	
Rumen development						
low	% rumens	60.04	2.44	0.00	0.04	***
moderate	”	28.40	1.53	0.32	0.40	***
well	”	9.86	1.19	26.70	3.74	***
full	”	1.10	0.24	72.98	2.14	***
Mean rumen development[1]	score 1-4	1.52	0.04	3.73	0.08	***
Rumen plaques	% rumens	31.17	1.89	0.44	0.53	***
Rumen hyperkeratinisation	”	6.06	0.54	1.81	0.63	***
Abomasal lesion						
presence in pyloric region	% abomasa	73.63	1.13	56.88	2.69	***
presence on torus	”	76.50	1.07	44.58	2.67	***
Mean abomasal score[2]	score 0-24	4.32	0.23	2.26	0.48	***

*** = P<0.001
[1]score calculated as mean of the scores of all the rumens observed per batch (from 1 to 4)
[2]score weighed according to the number of lesions (from 0 to max 4, censored) and size category (1= <0.5 cm²; 2=0.5-1 cm²; 3= >1 cm²) calculated as = [(n. of lesions size 1 x 1) + (n. of lesions size 2 x 2) + (n. of lesions size 3 x 3)].

RISK FACTOR ANALYSIS

Risk factor analysis for clinical/health problems

The prevalence of problems recorded during the *in vivo* assessment was always low and below 5%, set as minimum frequency to perform the risk factor analysis (see Chapter 3). Therefore no risk factor analysis was carried out for the variables recorded *in vivo* during the three clinical/health visits at the farms. A case study would be interesting to further investigate potential causes of bloating in those farms that showed a high maximum and that could be considered outliers in the current study.

Risk factor analysis for low rumen development

Regarding low rumen development, due to the high prevalence and the big difference among the two production systems, the analysis was restricted to 171 White veal farms aiming to identify the predisposing causes that characterize this type of veal meat production. The first one-way logistic regression analysis showed that potential risk factors were mainly related to housing facilities such as the type of housing system, the space allowance and type of floor, presence in the farm of a dedicated sickbay and to the feeding strategies (P<0.1). Looking at the outputs in Table 5.4, it was interesting to notice that delivering low amounts of solid feed, below or equal to 50 kg DM/head/cycle increased for almost 15 times the risk of poor rumen development (score 1) as compared to feeding high quantities of solids (150-300 kg DM/head/cycle). This variable alone explained almost 30% of the variance related to low rumen development. In farms where maize silage or pellets/mixture were used as prevalent types of solid feeds the risk of low rumen development increased with an OR of respectively 4.2 and 4.4 in comparison to farms where cereal grain was distributed. The milk delivery system also significantly interfered with underdevelopment of the rumen (P<0.05). While the pairwise comparison among buckets and troughs was not relevant, the risk of low rumen development increased for more than twice when comparing both systems to the AMD. The absence of a dedicated sickbay, and the slatted wooden floor showed also odds ratios over 1 (Table 5.4).

Table 5.4 Significant risk factors, odds ratio, 95% confidence interval and t pairwise comparison for the prevalence of low rumen development in White veal calves (one-way logistic regression analysis).

Risk factor	Level of comparison I	Level of comparison II	OR	95% CI		*t* pairwise comparison
				Lower	Upper	
Total amount of solid feed (kg DM/calf/cycle)	Low (≤50)	High (150<x≤300)	14.75	5.34	40.70	***
Prevalent type of solid feed	Maize silage	Cereal grain	4.21	2.27	7.80	***
”	Pellets or mixture	Cereal grain	4.43	2.38	8.27	***
Milk delivery system	Bucket	AMD	2.48	1.18	5.22	*
”	Trough	AMD	2.05	1.06	3.99	*
Sickbay	No	Yes	1.95	1.26	3.03	**
Type of floor	Slatted wood	Concrete	3.34	1.85	6.36	***

* = t<0.05; ** = t<0.01; *** = t<0.001
Single factors significant for P<0.05

Due to confounding effects with other factors total amount and type of solid feed were not included in a final multivariate regression model that considered type of housing system during fattening, total amount of milk-powder, water provision and season at housing (Table 5.5). Looking at pairwise comparisons among the OR for low rumen development considering total amount of milk-powder delivered and water provision they were always below 1, meaning that the classes defined for these factors in our study were not risks for low rumen development. Support to the positive result observed for the AMD, the housing of claves in large groups was a protective factor for poor rumen development compared to small groups (Small vs. Large OR=2.74, t<0.05). Farms where animals were housed during summer showed the lowest incidence of lowly developed rumen while when housing season was spring instead of summer the odds ratio of increased risk was 14.9.

Risk factor analysis for occurrence of rumen plaques and of rumen hyperkeratosis

Considering that Spearman rank correlation between occurrence of rumens plaques and rumen hyperkeratosis was rather low (r=0.37, P<0.01) the risk factor analysis was further carried out for the occurrence of both disorders. Once again, because the prevalence of both disorders was below 5% in the Rosé system the analysis was restricted to the sole White veal farms.

Table 5.5 Multivariate regression model for low rumen development in White veal calves.

Risk factor	Level of comparison I	Level of comparison II	OR	95% CI		*t* pairwise comparison
				lower	upper	
Total amount of milk-powder (kg/calf/cycle)	280<x≤330	330<x≤380	0.29	0.14	0.58	***
	280<x≤330	>380	0.14	0.06	0.30	***
	330<x≤380	>380	0.48	0.29	0.80	**
Water provision	Ad libitum	Limited	0.31	0.17	0.56	***
	Ad libitum	No water	0.10	0.04	0.22	***
	Limited	No water	0.31	0.15	0.65	**
Housing system during fattening	Small	Large	2.74	1.10	6.82	*
Season at housing	Spring	Summer	14.90	6.58	33.73	***
	Spring	Autumn	2.80	1.44	5.45	**
	Spring	Winter	0.94	0.46	1.90	ns
	Summer	Autumn	0.19	0.09	0.37	***
	Summer	Winter	0.06	0.03	0.13	***
	Autumn	Winter	0.34	0.18	0.61	***

ns = non significant; * = t<0.05; ** = t<0.01; *** = t<0.001
Model considers Season at housing, Total amount of milk-powder, Water provision and Housing system during fattening; Adjusted R^2=47.94%
All factors in the model were significant for P<0.001

From the one-way logistic regression analysis it was interesting to notice that within factors related to housing facilities and management, space allowance, type of floor, presence of a sickbay and of a ridge, the adoption of individual separators (baby-boxes) during the first weeks of rearing, use of heating, calves origin, and season at housing were significant (P<0.1) risks for rumen plaques (Table 5.6). All risk factors related to the feeding system reported in Table 2.4 significantly affected rumen plaques (P<0.01) except for the type of milk delivery system that was not relevant. Pairwise comparisons between levels of different risk factors reported in Table 5.6 showed that feeding low amounts of solids compared to high quantities decreased the risk of rumen plaques with an OR of 0.13. The opposite situation regarded the total amount of milk replacer diet where feeding low amounts increased the risk of developing rumen plaques for more than 10 times. Calves that did not receive at least two milk meals a day (diet restriction for one day/week, usually on Sundays animals were fed only once) showed a higher risk of plaques on the rumen wall compared to calves that were always fed 14 liquid meals per week.

Noteworthy was that in farms that reared national calves, and that did not adopt heating and individual baby-boxes at the early stage showed an increased risk of developing plaques while slatted wooden floors, absence of a specific sickbay and when manure under the calves the OR was below 1.

Most important is the multivariate risk factor model that shows the high association between occurrence of rumen plaques and type of solid feed, water provision, and space allowance (Table 5.7). The odds ratios in farms where animals were fed prevalently maize silage compared to the other 3 types of solids showed a lower risk for rumen plaques. The highest prevalence of rumen plaques resulted for calves that were fed cereal grain, indeed pairwise comparisons showed that it was a risk factor. Pairwise comparison among *ad libitum*, limited or no water provision showed always an OR higher than 1, likely suggesting that water provision was a risk factor for the rumen plaques. A space allowance just about the recommended measure increased twice the risk for rumen plaques compared to giving to each calf larger space.

Table 5.6 Significant risk factors, odds ratio, 95% confidence interval and t pairwise comparisons for the incidence of rumen plaques in White veal calves (one-way logistic regression analysis).

Risk factor	Level of comparison I	Level of comparison II	OR	95% CI Lower	95% CI Upper	*t* pairwise comparison
Total amount of solid feed (kg DM/calf/cycle)	Low (≤50)	High (150<x≤300)	0.13	0.06	0.25	***
Total amount of milk-powder (kg/calf/cycle)	Low (280<x≤330)	High (>380)	10.59	5.85	19.17	***
Calves always received ≥14 liquid meals/week	No	Yes	1.99	1.19	3.33	*
Calves origin	National	From more countries	1.94	1.22	3.08	**
Type of floor	Slatted wood	Concrete	0.31	0.19	0.51	***
Sickbay	No	Yes	0.64	0.44	0.93	*
Heating	No	Yes	3.28	2.00	5.39	***
Manure	Under the calves	Scraped outside	0.51	0.34	0.76	***
Use of baby-boxes	No	Yes	1.92	1.19	3.11	**

* = t<0.05; ** = t<0.01; *** = t<0.001

Single factors significant for P<0.05

Table 5.7 Multivariate regression model for the incidence of plaques on rumen wall in White veal calves.

Risk factor	Level of comparison I	Level of comparison II	OR	95% CI lower	95% CI upper	*t* pairwise comparison
Prevalent type of solid feed	Maize silage	Pellets or mixture	0.56	0.37	0.85	**
	Maize silage	Cereal grain	0.21	0.13	0.35	***
	Maize silage	Treated maize	0.60	0.29	1.28	ns
	Pellets or mixture	Cereal grain	0.38	0.24	0.60	***
	Pellets or mixture	Treated maize	1.08	0.54	2.18	ns
	Cereal grain	Treated maize	2.83	1.34	5.99	**
Water provision	Ad libitum	Limited	2.17	1.44	3.26	***
	Ad libitum	No water	2.58	1.57	4.25	***
	Limited	No water	1.19	0.73	1.95	ns
Space allowance (m²/calf)	≤1.8	>1.8	2.08	1.40	3.10	***

ns = non significant; ** = *t*<0.01; *** = *t*<0.001
Model considers Prevalent type of solid feed, Water provision and Space allowance; Adjusted R^2=31.51%
All factors in the model were significant for *P*<0.05

The one-way logistic regression analysis showed that risk factors for rumen papillae hyperkeratinization were type and amount of solid feed, type of milk delivery system, breed of the calves, type of floor, presence of a specific sickbay and manure management (*P*<0.1). Feeding animals in individual buckets compared to common troughs decreased the risk of rumen hyperkeratinisation (Table 5.8). Animals that received low amounts of solid feed had a lower risk of rumen hyperkeratosis compared to those that were fed amounts from 150 to 300 kg DM/head cycle (Table 5.8). Regarding the prevalent breed, it seems that Holstein cattle compared to crossbred animals had a lower risk of developing hyperkeratinisation of the papillae (Table 5.8).

The risk factor mostly associated to occurrence of rumen hyperkeratosis was indeed the type of solid feed, included in the multivariate risk factor model with the presence of a specific sickbay (Table 5.9). Feeding cereal grain only or as the prevalent component of the diet highly increased the risk of rumen papillae hyperkeratinisation Furthermore, farms that did not have a dedicated sickbay likely represented a risk.

Table 5.8 Significant risk factors, odds ratio, 95% confidence interval and t pairwise comparisons for the prevalence of rumen papillae hyperkeratinization in White veal calves (one-way logistic regression analysis).

Risk factor	Level of comparison I	Level of comparison II	OR	95% CI Lower	95% CI Upper	*t* pairwise comparison
Milk delivery system	Bucket	Trough	0.32	0.18	0.57	***
Total amount of solid feed (kg DM/calf/cycle)	Low (≤50)	High (150<x≤300)	0.38	0.16	0.90	*
Prevalent breed	Holstein	Crossbred	0.50	0.32	0.79	**
Space allowance (m^2/calf)	≤1.8	>1.8	2.72	1.64	4.52	***
Manure	Under the calves	Scraped outside	2.25	1.34	3.78	**

* = *t*<0.05; ** = *t*<0.01; *** = *t*<0.001
Single factors significant for *P*<0.05

Table 5.9 Multivariate regression model for the incidence of rumen papillae hyperkeratinisation in White veal calves.

Risk factor	Level of comparison I	Level of comparison II	OR	95% CI lower	95% CI upper	*t* pairwise comparison
Prevalent type of solid feed	Maize silage	Pellets or mixture	0.82	0.53	1.26	ns
	Maize silage	Cereal grain	0.40	0.25	0.63	***
	Maize silage	Treated maize	35.34	0.60	2068.66	ns
	Pellets or mixture	Cereal grain	0.49	0.31	0.76	**
	Pellets or mixture	Treated maize	43.03	0.73	2520.38	ns
	Cereal grain	Treated maize	88.53	1.51	5196.27	*
Sickbay	No	Yes	1.66	1.12	2.44	*

ns = non significant; * = *t*<0.05; ** = *t*<0.01; *** = *t*<0.001
Model considers Prevalent type of solid feed and Presence of a specific sickbay; Adjusted R^2=17.64%
All factors in the model were significant for *P*<0.05

Risk factor analysis for occurrence of abomasal lesions in the pyloric area

Spearman rank correlations showed that % of abomasa with lesions in the pyloric area was highly correlated to the % of abomasa with a lesion on the torus pylorus (*r* =0.62, *P*<0.01), and with the mean abomasal score (*r* = 0.86, *P*<0.01). Risk factor analysis was therefore carried out for occurrence of lesions in the pyloric area that showed a prevalence by far above 5% in both types of veal meat production systems.

The analysis in the univariate mode showed that there were not relevant risk factors among feeding strategies for lesions in the pyloric area regarding abomasa from Rosé calves. Season at housing and the presence in the farm of a dedicated sickbay were the only significant effects (*P*<0.1). Risk factors in White veal farms were mainly linked to feeding strategies (total amount of solid feed and of milk-powder, type of solid feed, water provision). Other factors were age of the floor, use of heating, season at hosing and frequency of veterinarian visits (*P*<0.1). Significant pairwise comparisons are reported in Table 5.10. Low amounts of solid feed delivered to each calf during the rearing cycle reduced the risk of abomasal lesions compared to high amounts while the opposite situation was observed for the amounts of milk-powder. The highest prevalence of lesions in the pyloric area was observed when calves were fed cereal grain, indeed the OR was below 1 for comparisons of maize silage and pellets or mixture with cereal grain while it was 2 comparing cereal grain and treated maize. No use of heating and adoption of new floors seemed being risk factors.

A multivariate regression model for abomasal lesions in the pyloric area was built taking into account both types of veal meat production systems in order to find out what are the causative factors of the high prevalence of the problem (Table 5.11). The risk of having at least one lesion on the pylorus was twice if calves were reared according to the White veal production system compared to Rosé. Small group housing, natural ventilation compared to dynamic and less frequent veterinarian visits throughout the rearing cycle reduced the risk of abomasal lesions while giving animals a lower space allowance increased such risk. Animals that were housed during summer had the highest risk of developing abomasal lesions.

Table 5.10 Significant risk factors, odds ratio, 95% confidence interval and t pairwise comparisons for the prevalence of abomasal lesions(at least one lesion, from superficial scar to ulcer) in the pyloric area in White veal calves (one-way logistic regression analysis).

Risk factor	Level of comparison I	Level of comparison II	OR	95% CI		*t* pairwise comparison
				Lower	Upper	
Total amount of milk-powder (kg/calf/cycle)	Low (280<x≤330)	High (>380)	2.14	1.41	3.24	***
Total amount of solid feed (kg DM/calf/cycle)	Low (≤50)	High (150<x≤300)	0.35	0.22	0.57	***
Prevalent type of solid feed	Maize silage	Cereal grain	0.54	0.38	0.76	**
”	Pellets or mixture	Cereal grain	0.57	0.40	0.80	**
”	Cereal grain	Treated maize	2.00	1.21	3.32	**
Water provision	Ad libitum	No water	1.71	1.23	2.37	**
Heating	No	Yes	1.77	1.36	2.31	***
Floor age (years)	New (≤4)	Old (>8)	1.51	1.05	2.18	*

* = t<0.05; ** = t<0.01; *** = t<0.001
Single factors significant for P<0.05

Table 5.11 Multivariate regression model for the prevalence of abomasal lesions (at least one lesion, from superficial scar to ulcer) in the pyloric area in veal calves.

Risk factor	Level of comparison I	Level of comparison II	OR	95% CI lower	95% CI upper	*t* pairwise comparison
Type of veal meat production	White	Rosé	1.99	1.59	2.50	***
Housing system during fattening	Small	Large	0.76	0.58	1.00	*
Frequency of visits by veterinarian/cycle	<3	≥3	0.70	0.57	0.85	***
Space allowance (m^2/calf)	≤1.8	>1.8	1.13	0.92	1.39	ns
Ventilation	Natural	Dynamic	0.55	0.44	0.69	***
	Natural	Both	0.94	0.72	1.22	ns
	Dynamic	Both	1.70	1.35	2.14	***
Season	Spring	Summer	0.78	0.60	1.01	ns
	Spring	Autumn	1.20	0.92	1.56	ns
	Spring	Winter	1.70	1.30	2.23	***
	Summer	Autumn	1.54	1.19	1.98	**
	Summer	Winter	2.18	1.68	2.83	***
	Autumn	Winter	1.42	1.10	1.83	**

ns = non significant; * = *t*<0.05; ** = *t*<0.01; *** = *t*<0.001
Model considers Season at housing, Type of veal meat production system, Frequency of veterinarian visits, Housing system during fattening, Space allowance, Ventilation; Adjusted R^2=33.81%
All factors in the model were significant for *P*<0.05

DISCUSSION

The White veal production system was a key risk factor for low rumen development, occurrence of plaques on the rumen wall and rumen papillae hyperkeratinisation. Abomasal lesions were observed with a high prevalence in both White and Rosé calves but White veal production showed a worse situation.

The large majority of descriptors regarding the feeding strategies had a significant association with occurrence of digestive disorders in White veal calves. Regarding rumen development, results of the present study confirmed findings in literature that underlined the importance of supplementing veal calves with solid feed to stimulate it (Beharka *et al*. 1998; Morisse *et al*., 2000; Cozzi *et al*., 2002; Suáres *et al*., 2006). Low amounts of solid feed were an important risk for low rumen development validating the theory that even if the forestomach increases in size innately with age, its papillae development results from physical stimulation and microbial fermentation (mainly butyrate and propionate) of roughage products (Beharka *et al*. 1998). The higher propionate production promoted by a starchy substrate like cereal grain stimulated a higher rumen development when compared to more fibrous feeds like maize silage or pellets. Compared to cereal grain, feeding prevalently maize silage and pellets or mixture provoked a higher risk of occurrence of rumens with almost no papillae (score 1). The results obtained with maize silage ars fully in agreement with recent findings from Guizzardi *et al*., (2007) who observed 80% of rumens with no papillae development when calves were fed maize silage. Unexpectedly, the provision of different amounts of milk-replacer diet, in quantities far above those given to weaned calves, did not directly interfere with low rumen development even if it might have interfered through the intake of solids (Suáres *et al*., 2006). If the explanation of risk factors associated to low rumen development among feeding parameters is biologically driven, other risk factors are more difficult to be explained. The increased risk for low rumen development related to delivering milk in buckets or troughs compared to the automatic teat-based milk delivery device was likely linked to the type of solid feed distribution. Where milk is automatically delivered usually also solids are distributed by computer controlled feeders. These devices probably allow a more balanced intake of solids among all pen-mates avoiding that a few dominant calves eat a large amount of roughage as in systems where feeds are delivered in common mangers. Support to this hypothesis is the increased risk of low rumen development observed for calves housed in small groups compared to large groups considering that the automatic feeding stations are only for groups that vary from 20 to up to 80 calves/pen (Bokkers and Koene, 2001).

The association of a high risk of plaques on the rumen wall and the consumption of cereal grain as prevalent type of solid feed was the core result in regards to this alteration. This is consistent with the results from Suáres *et al*., (2006) who found out that supplementing concentrate diets to veal calves increased weight of the empty rumen and thickness of the rumen mucosa but it increased also the incidence of rumen plaques. Considering that in most cases cereal grain (mainly maize or barley) is delivered alone it is likely that, among feed classes in the present study, it was the feed with the highest starch/fibre ratio. The same Authors reported a prevalence of 100% of calves interested by rumen plaques at 12 weeks of fattening adopting a mixed ration and a not significantly lower incidence of 73% with a starch diet. Water provision seemed being a further risk factor in White veal farms. However, it must be pointed out that in all Rosé veal calves farms water was provided *ad libitum* and there was no occurrence of rumen alterations. Other highly relevant risk factors for rumen plaques as the space allowance could be related to a higher welfare status for calves housed with a larger space allowance. More space offers the possibility to lay in a more comfortable way and likely to ruminate or it simply reduces stress and consequently enhances healthiness of the rumen but no literature references can be found for association of rumen plaques and these factor.

Similarly to rumen plaques, the results obtained in the current study for causative factors of rumen papillae hyperkeratinization showed the high risk associated to the feeding of cereal grain as a high concentrate solid feed. It validates the association between high-starch/low-fibre starter diets and accumulation of keratinized epithelium on rumen papillae. Bertram *et al*., (2009) reported that highly concentrated rations for calves induced high ruminal propionate concentrations compared to low-starch/high-fibre diets. Indeed, rumens of calves fed propionate and butyrate (Hinders and Owen, 1965) or a diet with a low acetate/propionate ratio (Gilliland *et al*., 1962) showed an excessive rumen papillae keratinization. Further evidence were collected by Hinders and Owen (1965) who reported that parakeratotic rumens were observed in calves and other young ruminants fed all-concentrate diets, rations in pelleted form or protein-deficient. According to Greenwood *et al*., (1997) hyperkeratinization is due to feed texture effects, and in particular to a low diet abrasive value. Finely grounded solid feeds compared to coarse diets induced differences in morphometric measurements of the rumen mucosa with a preponderance of extensively keratinized papillae. Looking at further results in the current study one of the protective factors seemed rearing prevalently Holstein calves compared to crossbred animals but this statement has to be considered carefully since it is likely that farms that rear prevalently dairy breeds use rations with a lower concentrate to fibre ratio.

In regard to abomasal lesions, the high prevalence observed was in agreement with those reported from previous studies (Groth and Berner, 1971; Wiepkema *et al*., 1987). Results regarding prevalence of lesions in the pyloric region were also in accordance with findings from a similar study recently carried out in Switzerland that compared the conventional White veal meat production to an innovative system “Naturafarm” with enhanced animal welfare requirements such as minimal duration of transport, later age of housing calves, lower stocking density and permanent access to an outdoor alley and to fresh water and *ad libitum* roughage availability (Bähler *et al*., 2009). The Authors did not find significant differences between the two productive systems considered in their study regarding abomasal lesions in the pyloric area. However they considered also anatomical location of the lesions on abomasa, reporting a much lower incidence of abomasal fundic part involvement.

In the current study both White and Rosé calves showed a high prevalence of abomasal lesions in the pyloric area and on torus pylorus, with a worse situation for White veal. Expectedly risk factors for the occurrence of lesions in White veal were related mainly to the amounts of solid feed and of milk replacer powder delivered to calves during the rearing cycle and to type of solid feed. However, contrary to findings reported in literature we did not find associations between abomasal lesions and the type of milk delivery system (Degen, 1982; Bähler *et al*., 2009). Regarding water provision our results were controversial since water provision seemed being a risk factor in White veal. Gottardo *et al*., (2002) found no effect while Bähler *et al*., (2009) found an odd ratio of 2.3 for lesions in the fundic area when water was not provided compared to free access to water. High amounts of milk powder were risk factors for abomasal lesions confirming hypothesis that overloading abomasum with large amounts of liquid diet delivered at once in two or less meals/day increased damage (Groth *et al*., 1979) while low amounts of solids could be considered protective factors. According to literature too rough solid feeds enhanced abomasal lesions (Cozzi *et al*., 2002; Mattiello *et al*., 2002; Bähler *et al*., 2009), but looking into our data, type of roughage and particularly cereal grain was also a causative factor.

Since none of the factors considered in the present study clearly explained etiology of abomasal ulcers further research has to be carried out, considering also additional factors such as pathogens (*Clostridium Perfringens*, Bovine virus diarrhea virus, etc.) mineral deficiencies and stockman attitude as potential risks implicated in the occurrence of abomasal damage (Mills *et al*., 1990; Lensink *et al*., 2000).

CONCLUSION

The cross-sectional study has been carried out on a large number of farms in the major veal calves producing countries of Europe, it is likely therefore that the prevalence of digestive disorders revealed in the current paper closely reflected veal calves population status. White veal production system was a remarkable risk factor for all digestive disorders recorded during postmortem inspection, although abomasal lesions were present also in Rosé veal calves with a high prevalence. Considering that feeding strategies were the most noticeable difference among the two systems, they were also the underlined risk factors. Cereal grain seemed being a protective factor against low rumen development while it was the main causative feed for rumen plaques and for rumen papillae hyperkeratinization, as well as for abomasal lesions in the pyloric area. Since a shortcoming of the current study was that type of solid feed and quantity were confounded variables and the amount of water delivered to each calf was not measured further investigation should be oriented specifically towards these factors. Concentrate sources, roughness and particle size should be considered besides the type of solid feed. In most cases options that were adopted in order to improve veal calves welfare (i.e. the presence of a specific sickbay or higher space allowance) were associated to lower risk of gastrointestinal disorders. It is likely that digestive disorders may be exacerbated by a higher stress level of the calves caused by bad farm management or a negative stockman attitude.

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Chapter 6

GENERAL CONCLUSION

This thesis aims at providing an understanding of the health and welfare status of veal calves at the batch level and on the risk factors that act as predisposing agents of common health problems of this livestock category. In order to give a complete and clear picture of the research topic the veal meat production systems present nowadays in Europe were described, the welfare issue was pointed out and the potential risk factors for veal calves welfare were reviewed in the first chapters of the thesis.

Veal calves production is a by-product of the dairy industry since it is based on raising mostly surplus male dairy calves that could not be implemented for milk production and belong to pure breeds or cross-bred with genotypes that are unsuitable for beef production. The European conventional ultimate product is comparable to white veal meat in Canada and special-fed veal in the USA. In the last decades in Europe, this type of rearing underwent to a drastic change in terms of housing and feeding strategies with the aim of increasing the animal welfare. However, the recent campaigns and responses against white veal meat point out that veal calves well-being is still an outstanding issue among European citizens.

Disease prevalence and their association with risk factors is an important research topic in preventive veterinary medicine as shown by recent literature addressed to animal categories as pigs and sows, adult dairy cows, dairy calves and veal calves. This confirms the increased attention towards farm animal health and welfare, but also underlines the importance of including risk factor analysis in assessment schemes that aim at improving animal rearing conditions.

STRENGHT AND WEAK POINTS

Main strength points of the research illustrated in the present thesis was the full involvement of scientists, industry and farmers of the three major veal meat producing EU Countries and the application on field of the protocols on a wide sample of farms (224) that allowed gathering of a large dataset. Moreover, the statistical procedures for the union and analysis of data were explicitly set for this type of study in GenStat and they resulted a helpful tool to obtain prevalence, odds ratios and the 95% confidence interval, having farm as experimental unit. The adopted approach was similar to that of PROC GENMOD of SAS and according to Kaps and Lamberson (2004) this kind of analysis is a very good implement for the comparison of farms.

A further *pro* of the strategy implemented in the current work is that the seek for critical points for health status of veal calves, besides identifying important risk factors allowed also to compare prevalence of clinical/health problems between White and Rosé meat production systems. In particular, the comparison between the two systems was important since Rosé veal production claims better welfare conditions for calves.

The present thesis focused on the most common calves respiratory diseases and digestive disorders excluding diarrhoea, mortality and other relevant health problems. This could be interpreted as a weak point, however, certain measures were left out on purpose due to the difficulty to obtain in an accurate and validated outcome. Problems at the locomotory and integumentary systems and the behavioural pattern will be topic of further studies. The threshold prevalence of 5% as limit for the analysis of risk factors that affect the variable was deliberately chosen even thou problems with a lower prevalence (e.g. abnormal breathing and bloated rumen) could be detrimental for the calves well-being. However, there are no existing international guidelines on the risk assessment in the field of animal welfare and literature regarding preventive veterinary medicine considers problems with prevalence ranging from 5% in the case of foot lesions in post-weaning pigs to over 70% of veal calves involved by abomasal lesions in the pyloric area.

In accordance with literature, risk factors in these studies were scrutinized among type of production and housing system, specific batch characteristics, management, farmer experience and feeding data obtained by a questionnaire. Avoidance of interactions between factors and of confounding effects permitted to fully distinguish each main factor separately and the strict retrospective approach allowed to study the hazards acting at different ages. These considerations increase robustness of this type of strategy. On the other side, a weakness of the approach adopted in the current work was the lack of prioritising or ranking risks in terms of severity, duration of the effect and reliability of the measure. Moreover, the quantitative type of information given by the odd ratios and the 95% confidence intervals does not give a simple description of the probabilities for a hazard to develop an adverse effect as “high”, “medium”, “low” or “negligible” offered by qualitative methods.

IN PRACTICE

The farm sample reflected European veal calves production with a large majority adopting the conventional white veal rearing system in small groups and a minor part rearing calves for Rosé veal meat production. Results obtained by this thesis could therefore be inferred to European veal calves production. Statistical inference on farms outside these systems is, however, implausible since our sample included only a single farm where veal calves were allowed to an outdoor run for the entire fattening period (Rosé) and only one farm that followed the organic label rules (Rosé).

The application of the welfare assessment scheme proved to be a very effective tool for the fast identification of the common disorders in veal calves. Even though, prevalence of gastrointestinal and respiratory problems recorded during the three on-farm clinical/health visits were low its routinely application could be useful for their prompt identification. Outcomes of *post-mortem* measurements resulted in substantial health problems, particularly when pleuritis and abomasal damage were concerned. This points out the importance of the observations at the slaughterhouse.

Comparison of the two types of production do not allow us to draw, in this thesis, robust conclusions of the better status of animals in the Rosé farming system as expected from its description in Chapter 1. Calves reared for pink meat showed expectedly well and full rumen development and likely better gastrointestinal health but a worse situation for respiratory diseases. The number of pharmaceutical treatments was however not assessed. Low rumen development, ruminal papillae hyperkeratinization and rumen plaques occurred principally in White veal calves confirming that the conventional system is the main risk factor. Among White veal farms, in general feeding strategies resulted being highly associated with gastrointestinal disorders. However, several other predisposing causes were found and risk factors for respiratory diseases were mainly linked to the housing environment, with forced/dynamic ventilation in first place, as well as certain managerial choices and feeding strategies. Calves that were reared throughout winter season showed a higher risk of clinical or *post-mortem* signs of pneumonia confirming that environmental temperatures play an important role. Since general demographic differences between locations (e.g. altitude and environmental temperature and humidity) are obviously not characteristics that a farmer could change in order to improve welfare on the farm, Country in which calves were reared was not considered as a potential risk factor.

On the other side, the outcomes of this thesis could be already implemented by farmers/industry. Prevalence and risk factors identification could help them to focus attention towards underlined problems and to plan, with their advisors, appropriate hazard-oriented strategies for diseases prevention or control in planned time points and to fulfill animal needs. Existing data should, however, be integrated with information about number and type of pharmaceutical treatments as well as mortality rates and culling reasons.

FUTURE IMPLICATIONS

This thesis pointed out that some more steps are necessary for the achievement of a fully validated welfare assessment scheme that aims also at identifying risk factors for animal health and welfare. The first considers the inclusion of record keeping quality and farm-books check. Second is prioritizing and ranking of problems and of hazards acting at different ages based on expert opinion.

SUMMARY

Veal calves production has a long history and, despite the improvements imposed by regulations, calves welfare is still an outstanding issue within European citizens. The EU-27 yearly production is about six million calves with France in first place, followed by the Netherlands and Italy. Aim of this research was to gain knowledge on the actual health status of veal calves at the batch level and on the risk factors that act as predisposing agents of common health problems of this livestock category. The first two Chapters of the thesis aim at introducing the experimental trials. The conventional White veal rearing system and of the Rosé veal production are described, the welfare issue is pointed out and potential risk factors still present at the farms are reviewed.

A cohort study was carried out on 224 veal calves' farms representative of EU production in France (50), the Netherlands (150) and Italy (24) between 2007 and 2009. Among these farms 174 reared the conventional White while 50 grew Rosé veal, mainly in small group pens of 4-15 calves with fully slatted floor. Data were collected through the application of part of an animal-based welfare monitoring scheme on one batch/farm. It consisted of a questionnaire submitted to the farmer; three on-farm subsequent clinical/health visits (early, early-middle and final stage of the rearing cycle); and post-mortem inspection at the slaughterhouse. The animal-based measures permitted to obtain prevalence of respiratory (*in vivo* nasal discharge, abnormal breathing, and coughing; and *post-mortem* lung lesions and pleuritis) and of gastrointestinal disorders (*in vivo* bloated rumen and poorer body condition compared to batch mid-range; and *post-mortem* rumen development, rumen plaques and hyperkeratinization and abomasal lesions). Potential risk factors among environment and management-based data and specific batch characteristics were obtained by the interview to the farmer. Data were submitted to statistical analyses adopting a specific set of procedures in GenStat that allowed descriptive analysis and stepwise risk factor multivariate regression models. Risk factors were expressed as odds ratio with the 95% confidence interval.

Prevalence of respiratory and digestive problems recorded during the 3 clinical visits were low in both rearing systems (White and Rosé). Nasal discharge interested on average 6.2, 4.8 and 6.5% of calves at the 1st, 2nd and 3rd visit, respectively. The overall average prevalence of calves showing other clinical signs were ≤5% throughout the entire fattening cycle. At post-mortem inspection frequencies of organ involvement were higher. Sign of pneumonia and of pleuritis were observed on 52.4 and 25.1 % of lungs respectively. Poor rumen development, ruminal plaques and hyperkeratinization and abomasal pyloric-area lesions involved on average 49.1, 25.6 and 5.3 % of rumens and 70.6% of abomasa, respectively.

Type of veal meat production system (White vs. Rosé) showed significant differences regarding all the post-mortem measurements (P<0.05) except for the percentage of lungs that showed minimal

signs of pneumonia. White veal rearing system showed a worse situation regarding gastrointestinal disorders, while Rosé calves were mainly involved by respiratory problems and they showed a higher prevalence of moderate and severe signs of pneumonia and of pleuritis.

White veal production and the feeding strategies that characterize this rearing method were main risk factors for post-mortem signs of gastrointestinal disorders. The main hazards for rumen underdevelopment in White veal calves were the low amount (≤50kgDM/head/cycle) and type of solid feed provided (maize silage, pellets/mixture vs. cereal grain). Cereal grain was associated to ruminal plaques, papillae hyperkeratinization and abomasal lesions. Considering respiratory-system problems several risk factors were identified while natural ventilation acted as a preventive measure compared to forced.

Risk factors identified and described in this thesis could be implemented in field by farmers/industry, technicians or veterinarians in order to fulfil animal needs, to prevent disease outbreaks and/or to plan effective strategies for disease treatment and management. Outcome of this thesis could also be used as framework for further research in the field of animal welfare and health, and in particular for the assemble of animal welfare risk factor assessment international guidelines.

RIASSUNTO

La produzione del vitello a scopi alimentari ha una lunghissima tradizione. L'allevamento del vitello a carne bianca è stato ed è tuttora oggetto di discussione in particolar modo a causa della percezione negativa dello stato di benessere degli animali da parte dell'opinione pubblica. Il problema è sentito in particolar modo tra i cittadini dei Paesi Europei dove ogni anno vengono prodotti circa sei milioni di vitelli con al primo posto la Francia seguita dai Paesi Bassi e dall'Italia. Lo scopo di questa tesi è stato quello di valutare lo stato di salute dei vitelli e di individuare i fattori di rischio associati ai problemi sanitari più comuni di questa categoria di animali da reddito. I primi due capitoli della tesi introducono la parte sperimentale con una breve descrizione del sistema convenzionale di produzione del vitello a carne bianca e di quello, meno frequente, della carne rosata, con un richiamo sull'argomento benessere e con una panoramica dei possibili fattori di rischio per il benessere animale presenti in allevamento.

Lo studio in campo è stato condotto tra il 2007 e il 2009 e ha visto l'applicazione di un sistema di monitoraggio del benessere animale su un campione rappresentativo della produzione Europea di 224 allevamenti (50 in Francia, 150 nei Paesi Bassi e 24 in Italia). Il campione di aziende era composto da 174 allevamenti produttori di vitelli a carne bianca (White) e 50 di vitelli a carne rosata (Rosé), utilizzando come sistema di accasamento prevalente box multipli a pavimentazione grigliata per piccoli gruppi di 4-15 vitelli. Il sistema di monitoraggio consisteva in: 1) un questionario sottoposto all'allevatore e relativo alle strutture e al management aziendale in modo da ottenere le informazioni considerate come potenziali fattori di rischio, 2) tre visite cliniche dei vitelli condotte in allevamento in diverse fasi del ciclo (iniziale, metà e finale) e 3) l'ispezione *post-mortem* di una parte di questi al macello. Le rilevazioni basate sulle osservazioni degli animali hanno dato origine alle frequenze dei problemi respiratori (in vivo scolo nasale, dispnea e tosse; nel *post-mortem* segni di polmonite e pleurite) e gastroenterici (in vivo segni di gonfiore addominale e condizione corporea inferiore rispetto alla media del gruppo; nel *post-mortem* stato di sviluppo ruminale, presenza di placche ruminali, ipercheratinizzazione delle papille ruminali e lesioni abomasali). Le analisi statistiche sono state condotte in GenStat mediante un pacchetto di procedure specifiche per questo tipo di dati. Tali procedure hanno fornito sia semplici analisi descrittive che complessi modelli di regressione multifattoriali. I fattori di rischio sono stati espressi come odds ratio ovvero come probabilità che un determinato problema si verifichi e il rispettivo intervallo di confidenza al 95%.

Le frequenze dei problemi clinici relativi al sistema respiratorio e gastroenterico rilevati negli allevamenti sono risultate mediamente basse in entrambi i tipi di sistema di allevamento (White e Rosé). La presenza di scolo nasale si è osservata in media nel 6.2, 4.8 e 6.5 % dei vitelli

rispettivamente alla prima, seconda e terza visita. Gli altri problemi clinici in vivo hanno dato invece prevalenze inferiori o uguali al 5% nell'intero ciclo d'ingrasso. L'interessamento degli organi ispezionati al macello è risultato in frequenze maggiori. Segni di polmonite e pleurite erano presenti rispettivamente nel 52.4 e 25.1 % dei polmoni osservati; il 49.1, 25.6 e 5.3 % dei rumini presentavano rispettivamente basso sviluppo papillare, placche e ipercheratosi; infine il 70.6% degli abomasi era coinvolto da almeno una lesione nella regione pilorica.

Il sistema di produzione del vitello a carne bianca (White) e il tipo di alimentazione che lo caratterizza sono stati i principali fattori di rischio per i problemi gastroenterici mentre i problemi respiratori erano più frequenti nel secondo tipo di allevamento (Rosé). L'effetto avverso di una bassa quantità di alimento solido sullo sviluppo ruminale e della granella di cereali sull'insorgenza di placche e ipercheratosi ruminale sono alcuni esempi di fattori di rischio individuati per i vitelli a carne bianca mentre i fattori ambientali e la stagione hanno maggiormente influenzato l'insorgenza di problemi respiratori. Per quest'ultimi, la presenza in stalla di un'aerazione naturale agisce invece come un fattore di protezione.

I fattori di rischio descritti nella presente tesi possono risultare utili per gli allevatori, i loro consulenti tecnici o i veterinari per soddisfare i bisogni degli animali, per prevenire l'insorgenza di problemi e/o per pianificare in modo tempestivo ed efficace gli interventi da mettere in atto al loro manifestarsi. La presente tesi potrebbe essere inoltre utilizzata come spunto per ulteriori ricerche nel campo del benessere animale, ed in particolare per la messa a punto di linee guida internazionali relative all'analisi dei fattori di rischio.

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