The Veal Calves Industry in Israel and Worldwide; Implications of Legislation on Animal Welfare and Public Health

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ABSTRACT

The veal calf industry represents a relatively closed-in structure production system characterized by high economic value, intensive feeding practices, and a complex, controversial sector from both public health and animal welfare perspectives. The industry is of significant global economic importance, as it relies primarily on surplus male calves from the dairy industry. Historically, white veal production relied on liquid milk-replacer diets and iron restriction to achieve pale meat color, procedures associated with anemia, abnormal behaviors, and metabolic disturbances. Over the past two decades, European and Israeli legislation have introduced minimum welfare standards, including requirements for fiber provision, group housing, and minimum average blood hemoglobin concentrations. This review provides an overview of the regulatory evolution, nutritional management, antimicrobial use, behavioral disturbance implications, and public health considerations associated with veal production in Europe and Israel. In this article, we reveal that only 11 calves of 329 calves that were sampled had an insufficient blood hemoglobin concentration, representing 3.34% of all calves examined. We further present hemoglobin monitoring data collected by the Israeli Veterinary Services between 2002 and 2017, demonstrating group-level compliance with statutory requirements. Despite regulatory progress, challenges remain regarding metabolic health, iron management, antimicrobial resistance, and behavioral disturbances. A One Health perspective integrating welfare science, metabolic physiology, and antimicrobial stewardship is essential for sustainable veal production systems.

Keywords: Veal Calves; Animal Welfare; Iron Deficiency; Hemoglobin; Antimicrobial Resistance; Milk Replacer; Behavioral Indicators; One Health.

INTRODUCTION

Veal calves' production is a specialized livestock sector based primarily on surplus male dairy calves. While economically important, this system has historically raised significant ethical and welfare concerns. Traditional white veal production involved individual crate housing, exclusive milk feeding, and deliberate iron restriction to achieve a pale meat color, preferred by certain markets (1).

Over time, scientific evidence linking these practices to anemia, behavioral abnormalities, and impaired physiological development led to regulatory reform in Europe and subsequently in Israel. This review critically examines the current status of the veal industry, focusing on welfare, metabolic health, antimicrobial use, and public health implications (2).

In 2002, three dairy calf operations were active in Israel, in Batsra, Kfar-Yehoshua and Mehola. The Batsra farm (Farm Number 1) ceased rearing dairy calves several years ago. Similarly, the farm in Mehola (Farm Number 2) discontinued this activity in 2016, when it changed its definition. Additionally, the farm in Kfar-Yehoshua (Farm Number 3) was closed as well a few years after. At the moment of publishing the article, there are no veal farms operating in Israel. Nevertheless, in this article, we wish to publish the average blood hemoglobin monitoring data which was collected during the years the three farms were active. Monitoring conducted by Israeli Veterinary Services demonstrated that the Mean hemoglobin values were consistently above the required minimum of 7.3 g/dL (4.5 mmol/L). Overall, group averages ranged between 8.7 and 10.1 g/dL, exceeding regulatory requirements, although occasional individual calves were found falling below threshold values (notably in 2002, 2011, and 2017) (3). These findings indicated regulatory compliance at the group level, although individual variations persisted.

GLOBAL INDUSTRY OVERVIEW

Over 4.4 million veal calves were slaughtered in Europe in 2013, of which 1.2 million in the Netherlands, with over 90% of the veal calves raised in the Netherlands being exported mainly to Italy, Germany, and France. Leading European producers include France (27%), the Netherlands (27%), Italy (16%), Belgium (6%), and Germany (5%). In Switzerland, this industry is restricted, and is prohibited by welfare standards in Scandinavia (4). France produces nearly 30% of all European production, with 1.3 million veal calves slaughtered in 2014. Veal calves raised in France are kept on relatively small farms (225 head) compared to Belgium and the Netherlands (over 600), and, in addition, the farms are less specialized in veal calves, with 75% also raising additional cattle, compared to Belgium and the Netherlands (5).

Outside Europe, the USA accounts for 6% of the global industry, Canada for 4%, Australia for 4%, and New Zealand for 3% of the global industry (6). These countries also produce meat from calves that are slaughtered up to a week after calving, known as "Bobby calves", which in New Zealand is the common form of veal calf consumption (7). In Europe, the "Bobby calf" industry is small in Romania and Bulgaria (8).

Veal calf meat is considered of very high quality worldwide and has many nutritional benefits, such as favored carbohydrate content, low fat content, and tenderness. Its price worldwide is usually higher than that of any other meat. In 2008, dairy veal consumption in Europe was 1.6 kg per head per year, with the highest levels in France (4.1) and Italy (3.5) (8). The definition of "veal calves' meat" was established in Europe in 2008 (Regulation EC 566/2008), a legislation according to which the meat was divided into 3 categories: 1. "White veal calf meat," the meat is white in color, on a scale of 1-10. The calf is fed only milk or milk replacer and must be younger than 8 months old at the time of slaughter. This group is traditionally the largest consumed. 2. "Rosa veal" the calf is fed grains without milk replacer. The calves are also younger than 8 months old, but the color of the meat is redder, at11-14 on the scale, due to the distinctive diet. 3. "Veal calf meat 8-12 months of age." This meat is marketed locally under various names such as "Beef" in the UK, "Older rosé veal" in Ireland and the Netherlands, "Ternera" in Spain, and "Jeune bovin" in France.

The level of hemoglobin in the blood contributes only one-third to the meat coloration (9), and what determines the price of the meat is its degree of whiteness. Meat color significantly influences market value (1).

Today, most methods test hemoglobin levels several times during the growth period to comply with regulations and control the meat color (1). The industry's concern was that solid feed would reduce milk powder consumption and affect meat color. But this did not occur. For example, it turned out that wheat straw does not affect meat color, despite its high iron content, because the iron was not readily available.

In addition, wheat straw reduces abnormal licking behavior thereby, decreasing the risk of hairball formation in the rumen (10), and reduces feeding-box licking and other abnormal behaviors. However, grain in the feed causes ulcers in the abomasum, and solid feed that improves calves' behavior, while maintaining performance and preventing damage to their digestive system, which still remains a challenge (11).

Recent studies have examined replacing part of the milk replacer with concentrated feed (corn kernels, barley, etc.) and have found that this improves rumen development, increases feed utilization, and reduces abomasal scarring (12). In addition, this helps to store nitrogen for protein production, especially in the last weeks of fattening (13).

Providing water alongside the milk is not necessary from a health perspective, but is mainly used for the purpose of environmental enrichment. The calves receive all the fluids they need from the milk. Providing water freely throughout the day is not recommended because it can lead to overdrinking (14). There are farms around the world today which provide water in drips. (European directives 91/629/ EC and 97/2/ EC; KB 23 January 1998).

STRUCTURE OF THE VEAL INDUSTRY IN ISRAEL

In 2002, three veal calf operations existed in Israel; none are currently active. Historically, Israeli production mirrored European practices, including individual housing and predominantly liquid feeding. Israeli farms voluntarily adopted EU standards in 2002, before Israeli regulations were enforced in 2006. Current management includes the early introduction of concentrate alongside milk replacer to maintain adequate blood hemoglobin levels.

REGULATORY FRAMEWORK

European Union Legislation

Veal calf welfare within the European Union is governed by Council Directive 2008/119/EC (known as the "Calves Directive"), consolidating earlier directives from 1991 and 1997. Key provisions include: prohibition of feeding calves exclusively liquid diets (Since 1998), mandatory inclusion of daily fiber (50–250g per calf, age-dependent) from two weeks of age; dietary iron levels sufficient to maintain blood hemoglobin ≥ 7.3 g/dL (4.5 mmol/L); prohibition of housing calves in narrow individual crates preventing turning (since 2006); mandatory group housing from 8 weeks of age and minimum individual space allowance of 1.5 m^2 per calf and later widely applied to 1.8 m^2 per calf (15).

These regulations were based on measures and recommendations from the Scientific Veterinary Committee (SVC), which concluded that exclusive liquid feeding and iron deficiency may compromise welfare and physiological development.

Israeli Legislation

Israel enacted the Animal Welfare (Protection of Animals) (Holding of Veal Calves) Regulations in 2006 (16). A "veal calf" was defined as a calf raised for meat production and fed a milk-based diet or milk replacer.

The regulations require: concentrate feed must be provided from 4 weeks of age; hemoglobin monitoring must be conducted in calves aged 12–24 weeks; at least 10% of the herd (minimum 15 animals) must be tested, but without reference to the frequency of the test. The regulation refers to group mean blood hemoglobin levels rather than individual values. The threshold value for the average hemoglobin test should be equal to or greater than 7.3 g/dL (4.5 mmol/L), as in the European Union Legislation (15).

Testing was performed and financed by the Israeli Veterinary Services. Unlike EU legislation, Israeli regulation specifies group-level compliance rather than individual thresholds.

NUTRITIONAL MANAGEMENT AND METABOLIC IMPLICATIONS OF VEAL CALVES

Gastrointestinal Physiology

Worldwide, the diet of dairy calves today is mostly based on milk replacer, roughage, and concentrated feed. With milk replacer constituting 60-70% of the ration. Milk replacer contains a large amount of lactose and fat (approximately 45% and 20%, respectively) (17). Lactose is extracted from whey, which is a by-product of the cheese industry. Lactose is highly digestible and is the main source of energy in the ration (18).

However, the price of lactose is relatively high, and in order to reduce the price of milk replacer, attempts have been made to replace the carbohydrate source (lactose) from dairy to a vegetable one (e.g., corn starch).

It is known that this type of replacement alters the composition and, consequently, the digestibility of the milk replacer. A 2016 study examining the effects of replacing 18% of carbohydrates with starch on protein and fat digestibility found that the overall effect on digestibility was negligible (19).

Feeding milk replacer has physiological consequences on the calf's digestive system. When a calf is fed a liquid milk replacer, the esophageal-slit closes, allowing the milk to bypass the reticulo-rumen and reach the abomasum directly, and from there, to enter the small intestine. The nutrients from the milk replacer are digested in the small intestine, a process that resembles monogastric physiology rather than ruminal fermentation. This is in contrast to solid feed that enters the reticulo-rumen, where it is fermented by the rumen, producing bacterial proteins and volatile fatty acids (18).

Table 1. Mean blood hemoglobin concentration in the Farms along different sampling years.

Farm	Year	Number of Calves	Mean	SE
Mehola (2)	2011	54	8.72	0.19
	2013	66	10.1	0.11
	2017	100	10.03	0.12
Kfar-Yehoshua (3)	2002	12	10.09	0.67
	2011	81	10.06	0.16
	2013	16	9.83	0.24

SE: Standard error

Metabolic Consequences

Cattle are susceptible to acid-base imbalances that can lead to respiratory or metabolic acidosis or alkalosis. The high carbohydrate concentration in milk replacer (lactose >5%) can cause metabolic acidosis (20).

As mentioned, milk replacer contains a large amount of lactose and fat. Exposure to high levels of lactose and fat over time can disrupt blood glucose homeostasis, leading to hyperglycemia, hyperinsulinemia, and glycosuria. The problem is observed mainly in calves aged 4-6 months. Additionally, calves experience a significant decrease in insulin sensitivity during the first month of life (17). A study conducted in 2016 examining dairy calves fed a high-fat or lactose milk replacer found that insulin sensitivity values were low, and that 50% of calves developed insulin resistance (21).

In addition, dairy calves often develop problems with glucose homeostasis and insulin sensitivity, which can manifest as glucose excretion in the urine and liver damage. There are indications that high lactose levels in dairy calf feed are related to this by affecting glucose homeostasis (18).

HEMOGLOBIN MONITORING IN ISRAEL (2002–2017)

Approximately 8 mL of blood was collected from the jugular vein of each calf. The blood sample was divided into two 8-mL tubes: a serum tube (red cap) and a whole blood tube (purple cap). The samples were transported under refrigeration the same day to the laboratories of the Koret School of Veterinary Medicine in Beit Dagan, Israel, for blood hemoglobin concentration analysis.

Calves were sampled, in accordance with the regulations requiring the examination of at least 10% of the calves present on the farm that are between 12 and 24 weeks of age, provided that the number sampled is not fewer than 15 individuals.

Hemoglobin was measured in units of g/dL, with a minimum acceptable level of 7.3 g/dL. A normal value was defined as the mean hemoglobin concentration of all examined calves exceeding 7.3 g/dL.

Mean blood hemoglobin concentration in the Farms along different sampling years is presented in **Table 1**. Sampling was not performed at the Batsra farm.

Monitoring conducted by Israeli Veterinary Services demonstrated that mean blood hemoglobin values were consistently above the required minimum of 7.3 g/dL. As shown in **Figure 1**.

Overall, group averages ranged from 8.7 to 10.1 g/dL, exceeding regulatory requirements, although occasional individual calves were found below threshold values (notably in 2002, 2011, and 2017). These findings indicate regulatory compliance at the group level, although individual variation persists. A total of 11 calves out of 329 calves tested across all study years were found to have blood hemoglobin concentrations below the minimum threshold value, representing 3.34% of all calves examined.

IRON RESTRICTION AND WELFARE IMPLICATIONS

Iron-deficient diets are traditionally used to achieve pale meat color by reducing myoglobin concentration. However, an iron-deficient diet often causes iron-deficiency anemia (22). An iron deficiency diet may impair the well-being of calves and cause them to become ill due to impaired cellular immune response and increased infections (23). It can also cause increased lactate production (24) and im-

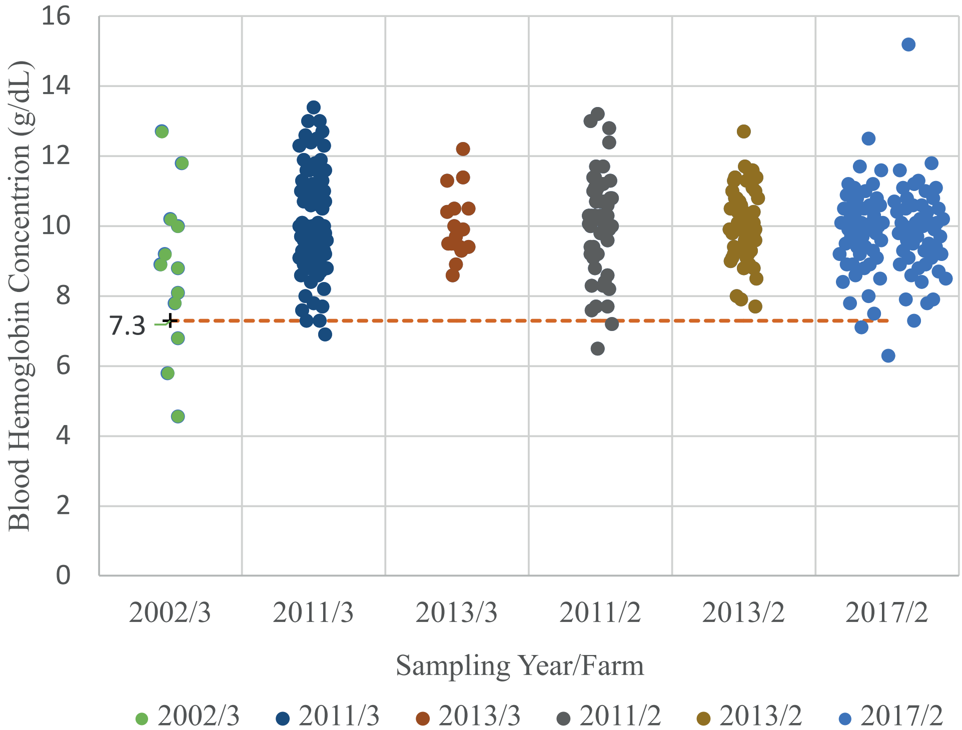

Figure 1: Blood hemoglobin concentration of veal calves in two farms in Israel, between the years 2002–2017. The colors indicate different sampling points in different farms in 2002, 2011, 2013, and 2017. The red dashed mark represents the minimum required hemoglobin concentration threshold value.

paired daily weight gain due to reduced daily food intake (25). Additional effects of iron deficiency are impaired O_2 oxygen transport (via hemoglobin), O_2 storage (via myoglobin), and O_2 utilization via respiratory enzymes (24).

According to the literature, calves with low iron levels exhibit low insulin levels (26), which can lead to elevated blood glucose levels. The normal level of hemoglobin in the blood of calves is 4.9-9.3 mmol/L (7.90-14.99 g/dL). A value below 4.9 mmol/L (7.90 g/dL) is considered anemia (27). In Belgium, the requirement is 7.7-8 mmol/L (12.40-12.89 g/dL) during the first weeks of growth and 4.9-6 mmol/L (7.90-9.67 g/dL) before slaughter.

The first physiological effect of iron deficiency anemia is a decrease in appetite, which occurs when the iron concentration in the food drops below 15 PPM (28).

Additional effects include damage to the immune system, resulting in hypersensitivity to various infections (pneumonia), and decreased growth (23). From a welfare perspective, intentionally inducing marginal anemia raises ethical concerns, particularly when motivated primarily by market preferences.

ANTIMICROBIAL USE AND PUBLIC HEALTH

Veal calves are frequently exposed to group antimicrobial treatments, particularly during the early fattening phase. Studies in Europe have reported significantly higher Defined Daily Doses (DDD) in veal calves compared to dairy cattle. According to a study conducted in France during 2017, dairy calves received an average of 8.5 antimicrobial treatments during fattening (5). The majority of the treatment was administered to the entire group during the first two weeks of growth while on the milk replacer. The main antibiotics used in the industry were tetracyclines and macrolides, which are less important in terms of human antibiotic resistance, but dairy calves are still considered a significant source of development of antibiotic resistance (5). Livestock-associated methicillin-resistant *Staphylococcus aureus* (LA-MRSA) was found in 88% of dairy calf farms in the Netherlands, and in

72% and 33% of farmers on these farms in the Netherlands and Belgium, respectively. These findings raised serious concerns in Western Europe about the zoonotic risks posed by dairy calf farms (29). In the Netherlands and Belgium, the average dairy calf is treated with antibiotics for 26.8 and 61 days per year, respectively, compared to 5.8 days of antibiotics per year for dairy cows (30, 31). These findings raise significant concerns about zoonoses and antimicrobial resistance. They highlight the relevance of the veal sector to discussions of antimicrobial resistance (AMR) and support the integration of antimicrobial stewardship programs.

BEHAVIORAL INDICATORS OF WELFARE

The veal calves rearing exposes them to conditions that do not meet all their physical and psychological and emotional needs. The calves were collected and mixed from multiple farms, separated from their mothers, fed milk replacer from a bucket feeding system, and were provided with a very small amount of non-drinkable food and limited roughage.

A study conducted in Europe between the years 2007 to 2009, attempted to estimate the prevalence of non-nutritive oral behaviors of veal farms and to determine the potential influencing factors present at the farm level (31). The study examined three main behaviors: 1. Licking, chewing, and sucking objects in the enclosure. 2. Rolling the tongue in and out of the mouth. 3. Sucking the body parts of other calves. These behaviors were most often observed around the time of feeding the milk replacer and are indicators of poor animal welfare. Previous studies have found that these behaviors account for 15 to 35% of all calf behaviors, and last for 15-20% of the time (31).

Behavior is considered abnormal when it is directed toward an unacceptable object, when it differs in manner or frequency from the behavior typical of this species in nature, and when it has no apparent function or is even harmful to that individual. For example, sucking on objects in a fence by calves is not considered abnormal behavior but is part of young calves' exploratory behavior. However, if it occurs frequently, especially around feeding, it is likely to be a source of frustration due to an inappropriate feeding method and therefore indicates poor well-being.

These behaviors represent coping mechanisms for chronic frustrations with an inappropriate environment. Performing these behaviors calm the calf and reduces its stress. Other individuals who do not show this behavior are probably individuals who suffer more because they have no way to calm themselves (32, 33). The experiment was conducted over two years on 157 farms in France, the Netherlands, and Italy.

In conclusion, the following welfare improving factors have a positive effect on reducing abnormal eating behaviors: 1. Feeding corn silage instead of corn kernels. 2. Feeding over 380 kg of milk powder per fattening cycle. 3. Larger living space per calf (over 1.8 m^2). 4. Rearing the calves in larger groups. 5. Individual housing during the beginning of the fattening (31).

The 1997 European Calf Directive states that calves should be fed fibrous feed in an amount between 50 and 250 g/calf/day, at the age between 8 and 20 weeks (15). The disadvantages of this legislation are that it makes no reference to particle size or the source of the fiber added to the feed. It is also not clear whether it refers to dry or fresh material. Studies have shown that this amount is insufficient and leads to abnormal eating behaviors, including playing and rolling the tongue, sucking on other calves, licking and chewing objects such as buckets, troughs, etc. (34, 35).

The idea is that these behaviors arise from frustration caused by a lack of chewing and rumination. These behaviors have been considered an indicator of chronic stress and impaired welfare (36).

In Europe, keeping calves in groups has been mandatory since 2007, and keeping them in individual cages is permitted up to 8 weeks of age (15). However, in the USA, keeping calves in groups is not mandatory (37). The minimum living space in a group from 8 weeks of age is 1.8 square meters per calf. The most common form of rearing in Europe is in groups (15, 35). In France, calves are reared in large groups of 30-60 individuals, and feeding is carried out allowing the calves to move around freely and eat as they please. In the Netherlands, play balls are added for enrichment (1).

DISCUSSION

The veal calf industry has historically represented one of the most controversial sectors of livestock production, primarily due to the inherent tension among economic drivers, meat quality preferences, and animal welfare considerations. Traditional production systems relied heavily on management practices aimed at producing pale-colored meat, including iron-restricted diets, exclusive liquid feeding, and restrictive housing conditions. Accumulating scientific evidence over the past three decades has demonstrated that these practices may negatively affect calves' health, behavior, and physiological development, prompting regulatory reforms in many regions, particularly within the European Union (15).

The implementation of the EU Calves Directive and similar welfare regulations in Israel has significantly altered the management of veal calves. Requirements for group housing, fiber inclusion, and minimum hemoglobin concentrations were designed to mitigate the welfare problems historically associated with veal production. These measures reflect a shift toward evidence-based welfare standards that balance production goals with calves physiological and behavioral needs.

The hemoglobin monitoring data collected in Israel between 2002 and 2017 provided valuable insight into the practical outcomes of these regulatory measures. The results indicated that mean hemoglobin concentrations consistently exceeded the regulatory minimum threshold of 7.3 g/dL, suggesting that, at the herd level, feeding management practices were sufficient to prevent severe iron-deficiency anemia. Nevertheless, the detection of occasional individuals with blood hemoglobin concentrations below the threshold highlights the biological variability inherent in intensive production systems and emphasizes the importance of continued monitoring.

An important aspect of the Israeli regulatory framework is its focus on group-mean hemoglobin values rather than individual-animal thresholds. While this approach facilitates practical monitoring and enforcement, it may mask the presence of individual animals' experiencing subclinical anemia. Similar discussions have emerged in European welfare assessments, where herd-level indicators are increasingly complemented by animal-based measures. Future regulatory frameworks may therefore benefit from integrating both approaches to improve the sensitivity of welfare assessment.

The threshold value established as the average regulatory cutoff in the Israeli regulation (7.3 g/dL) is considered, according to the literature, to represent anemia in cattle (27), thus it might be warranted to re-evaluate the minimal hemoglobin threshold required. In addition, the Israeli regulation does not specify the required frequency for performing hemoglobin testing. In light of the above, it seems that revision of the legislation may be needed in states where the veal calf's industry is still present.

From a nutritional and physiological perspective, veal calf production remains a unique system in which calves metabolize more like monogastric animals due to the predominance of liquid feeding. Diets based largely on milk replacer may influence carbohydrate metabolism, insulin sensitivity, and acid-base balance. Evidence suggests the development of hyperinsulinemia, insulin resistance, and metabolic disturbances in calves receiving high lactose diets raises questions regarding the long-term metabolic consequences of intensive milk replacer feeding strategies.

In addition to metabolic concerns, behavioral indicators provide important information regarding calf welfare. Abnormal oral behaviors such as cross sucking, tongue rolling, and object licking are widely recognized as indicators of environmental or nutritional frustration. These behaviors appear to be particularly associated with feeding management and with insufficient opportunities for chewing and rumination. Although the inclusion of roughage and group housing has improved behavioral outcomes, current minimum fiber requirements may still be insufficient to fully satisfy behavioral needs (34, 35).

As discussed earlier, an important dimension of the veal sector relates to antimicrobial use and its implications for public health. The intensive nature of veal calf production, combined with the mixing of calves originating from multiple dairy farms, increases the risk of infectious disease outbreaks. Consequently, antimicrobial treatments, often administered at the group level, are more common in veal production than in other cattle sectors, and significantly demonstrate higher antimicrobial exposure. This raises concerns about the development and dissemination of antimicrobial-resistant bacteria such as livestock-associated methicillin-resistant *Staphylococcus aureus* (LA-MRSA) (38, 39).

From a One Health perspective, the veal industry therefore represents an intersection between animal welfare, metabolic health, and antimicrobial resistance. Addressing these interconnected issues requires an integrated approach that combines improved nutrition, enhanced management practices, targeted disease-prevention strategies, and responsible antimicrobial stewardship.

Finally, the current situation in Israel, where veal production has ceased entirely, presents a unique case study. While the sector was historically small and closely regulated, its discontinuation reflects broader economic, ethical, and regulatory pressures affecting similar production systems in other regions. Nevertheless, historical monitoring data remain valuable for documenting the effectiveness of regulatory oversight and may serve as a useful reference for international comparisons.

CONCLUSIONS

The veal calf production system illustrates the complex interactions between animal welfare, production efficiency, consumer preferences, and public health considerations. Regulatory reforms implemented in Europe and Israel over the past two decades have significantly improved welfare conditions, particularly through the prohibition of restrictive housing, the introduction of fiber feeding, and the establishment of minimum hemoglobin thresholds.

The hemoglobin monitoring data collected by the Israeli Veterinary Services between 2002 and 2017 demonstrate overall good level compliance with regulatory requirements and suggest that appropriate feeding management can prevent severe iron deficiency in veal calves. However, individual variability persists, indicating that continued monitoring remains important. This evidence shows that a total of 11 calves out of 329 calves tested across all study years were found to have blood hemoglobin concentrations below the minimum threshold value, representing 3.34% of all calves examined. Despite improvements in welfare standards, several challenges remain. These include managing iron levels without inducing anemia, preventing abnormal behaviors associated with restricted diets, and reducing antimicrobial use in intensive calf rearing systems.

Future strategies for sustainable veal production should adopt a One Health approach, integrating animal welfare science, metabolic physiology, disease prevention, and antimicrobial stewardship. Such an approach will be essential for ensuring that livestock production systems remain ethically acceptable, biologically sustainable, and compatible with public health objectives.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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