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*Research Article*

# Biological constraints and on-farm limitations affecting meat rabbit productivity in Malta

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**Abstract.** Literature on the production characteristics and constraints of intensive commercial rabbit meat production in Malta is scarce. This paper presents the current situation of the sector as it emerged through questionnaires addressed to the various stakeholders and professionals working within the sector. Agriculture holdings in Malta are limited in size, thereby restricting farm design, which very often requires improvised adjustments and compromises based on the available footprint. Furthermore, Malta's geographical position is a consistent constraint whenever imports are required; hence, all manufacturing and production industries, rabbit production included, have a significant disadvantage over their European counterparts as there are added expenses associated with transport costs. Other constraints are that the sector is not organised to harmonise production. Furthermore, producers are in need to upgrade their skill sets with regards to the basic principles of husbandry and stockmanship.

**Keywords:** Malta, Meat rabbit, On-farm limitations, Biological constraints

## 1 Introduction

Rabbit production in Malta has always been an ongoing activity throughout the years, so much so that the role of rabbit meat in Maltese culture and gastronomy is well documented (Buttigieg & Cassar, 2020; Cassar, 1994, 2016). De Battista (1985) documents the gradual evolution of the rabbit meat sector in Malta. He claimed that the general scenario in post-war Malta was of rabbits kept on the floor in farmyards together with other livestock to produce a poor-quality carcass and at times being infected with coccidiosis as was evident from spots on the liver. The sector gradually evolved through the importation of foreign genetics, the availability of balanced feeds, improvements in housing and the continuous dissemination of knowledge and information through the Rabbit Breeders Association (De Battista, 1985).

Rabbit meat consumption has a strong historical culinary tradition in Malta. It is well entrenched into Maltese cuisine, culture, and traditions, so much so, that the Maltese national dish is cooked rabbit known as 'Stuffat tal Fenek' (Cassar, 1994, 2016; De Battista, 1985). A recent report by the Directorate-General (DG) for Health and Food Safety of 2017 estimates that the average per capita rabbit meat consumption is more than 3 kg, which is significantly higher than in any other European country. This rate of consumption translates to the production of market rabbits (1.5kg dressed carcass) from 20,000 does; hence a significant sector. Rabbits are very delicate and sensitive animals, having a complex biology in terms of their nutritional physiology and requirements, health and susceptibility to disease, reproductive capabilities, and their response to environmental conditions and stressors. Yet, despite Malta's long association with rabbit meat consumption, it appears that there is a lacuna in information regarding the constraints and challenges faced by this sector. However, a potential reservoir of accumulated knowledge and experiences is undoubtedly present among the various professionals and stakeholders involved in the local rabbit industry. Hence, this study aims to retrieve this information from the professionals and stakeholders using questionnaires to take stock of the current state of affairs with regards to the biological and on-farm constraints affecting the Maltese commercial rabbit meat sector, and in so doing present a baseline reference on which further research is based.

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| Type | Criteria | Number of people selected for interviews |
|---|---|---|
| Rabbit producers | Farms registered with VRD as having more than 50 breeding does | 11 |
| Feed mills | Local manufacturers and distributers of rabbit feed | 4 |
| Importers of feed and equipment | Importers of ready formulated rabbit feed and equipment | 3 |
| Veterinarians | Veterinarians known to be involved in the management of rabbit farms | 14 |
| Pharmacists | Pharmacists specialising in pharmaceutical products used in the livestock sector | 8 |
| Breed stock supplier | Supplier of imported breeding stock | 1 |

**Table 1:** Selection of participants.

## 2 Methodology

A qualitative research approach through the use of questionnaires was identified as the most suitable for this study since the data collected would reflect the personal perspectives and experiences of the selected participants.

**Questionnaire** The questionnaires were developed and designed following a review of similar studies found in the scientific literature. Four questionnaires were devised, three intended for professionals, addressed aspects of nutrition and feeding, rabbit health, farm biosecurity, and availability of genetics and a fourth was targeted at rabbit producers.

**Criteria for selection of participants** A background search to identify suitable professionals and stakeholders was conducted based on the criteria displayed in Table 1. A number of individuals who satisfied the criteria of having significant exposure to the sector were chosen, as presented in the following table.

**Conduction of the survey** The rabbit producers were interviewed in person. However, in the case of professionals, questionnaires were sent by email and followed up by a telephone call to encourage their participation. This study commenced on the 10th of December 2022 and was concluded by the 20th of February 2023.

**Data analysis** Results were analysed and interpreted using the Microsoft Excel Database.

## 3 Results

**The response rate of the survey** Registered an encouragingly high response and participation rate: rabbit producers 82%, feed mills 75%, importers of feed and equipment 67%, veterinarians 50%, pharmacists, 63% and the sole breeding stock supplier.

**Producers' knowledge and access to extension services** Feed suppliers offer their clients feeding advice usually based on the formulations that they represent. Results indicate that producers seek advice from veterinary pharmacists, other producers, online information, and the local rabbit breeder associations, but rarely from veterinarians. None of the producers referred to having any on-farm animal welfare issues, however, results indicate that few are aware of the basics of animal welfare principles.

**Farm layout and production unit design** Agriculture holdings in Malta are limited in size, thereby restricting farm design, which very often requires improvised adjustments and compromises based on the available footprint. All farms have comfortable and direct access through paved roads, and also connections with the municipal water and electrical supply networks. All units implement a closed-cycle production system, keeping the breeding stock and growing/finishing rabbits on the same premises and often in the same barn. The barns are constructed with locally available building materials and roofed over with concrete. In some instances, claims were made that the roofs were insulated to mitigate against the strong summer solar radiation. The widths and lengths

| Brand \ Ingredient | Alfalfa | Grass meal | Maize | Wheat bran | Wheat pollards | Wheat middlings | Triticale | Barley | Barley distillers dried grains | Barley straw | Sunflower meal | Sunflower | Sunflower hulls | Dehulled soybean meal | Soybean meal | Soya | Soy hulls | Soy lecithin | Peas | Carob pulp | Carob seed husk | Carob seed meal | Grape pips extracted | Rapeseed | Sugar beet pulp | Molasses | Calcium carbonate | Sodium chloride | Sodium bicarbonate | Monodicalcium phosphate | Dicalcium phosphate | Calcium phosphate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Local 1 | x | | | x | x | | | x | | | | x | | | x | x | | | x | | | | | x | | x | x | | | | | |
| Local 2 | x | | | x | | | | x | | | | | | | | x | | | | | | | | | | | x | | | | | |
| Local 3 | x | | | x | | | | x | | | x | | | | | | | | | x | | | | | x | x | x | x | | x | | |
| Import 1 | x | | | | | x | x | x | | x | x | x | | x | | | | | | | | | x | | x | x | x | x | | | x | |
| Import 2 | x | | | x | | | | x | | | | | x | | | | | | | x | | | | | x | x | x | x | x | | x | |
| Import 3 | x | x | | x | | | | | | | | | | | | | | | | | x | x | | | | x | x | | | | | |

**Table 2:** Ingredients used in different brands of breeding doe feeds.

of the barns are not standardised and reflect the limitations present site. All of the barns have doorways for access to the inside and high-level windows to let in light. None are naturally ventilated. Another aspect that reflects space limitation is the lack of an on-site workshop and office space or feed silos, while the presence of a quarantine/isolation holding facility is only available in a limited number of farms. Since no silos are present on any of the farms, they all purchase commercially-available balanced feeds in 25 kg bags. Manure and litter are regularly removed from the inside the barns and kept in a purposely built manure clamp according to the Maltese Code of Good Agricultural Practice (COGAP).

All the health specialists interviewed commented on the proximity of some farms creating clusters of livestock farms, which pose biosecurity threats. However, producers do not share the same concerns. The health professionals confirmed that producers underestimate the importance of on-farm biosecurity measures so much so that most producers confirmed the implementation of just a pest control programme, while completely ignoring even the most rudimentary ones, such as having disinfectant pits at each entry point to the farm. Other basic measures such as the presence and use of footbaths, the practice of showering of personnel before contact with the rabbits, and the use of clothing exclusively worn on-farm are not practised. Only 44% of the farms have toilet facilities on-farm, and in some cases also showers; while 22% use the toilet and shower facilities located in their nearby home. The larger commercial farms follow a supervised animal health control programme that includes vaccination programmes and records on the use of pharmacological products on-farm, whilst the smaller farms have an unsupervised home-developed programme.

Most producers claimed that their barns are adequately equipped with devices for the monitoring and control of the internal environment of the barn, including temperature, humidity, ventilation, and lighting programs. The types of cages found on the farms were procured from European manufacturers that specialise in rabbit equipment, with the most common design being either a flat deck, a two-tiered Californian-style design, or a combination of both. The type of cage system chosen is often determined by the production space available, as well as the production goals. All models are equipped with automated water supplies; however, feeding is mostly done manually.

**Feed availability and quality** All grains used by the local feed mills are imported, thereby the cost of locally manufactured feed is highly vulnerable to market fluctuations at the international level. The main imported ingredients include alfalfa, wheat bran, sunflower, pollard, barley, soya, other vegetable fibres, vegetable oil, vitamins, and minerals, with Europe and Ukraine being the main suppliers of raw materials. The local feed mills claim to match their formulation with the recommended French and Italian standards. Only one feed mill has a qualified in-house animal nutritionist capable of developing least-cost feed formulations and addressing producers' concerns. The other feed mills rely on the technical support from their pre-mix suppliers and on the cooperation with various veterinarians acting on behalf of the producers. All rabbit feeds on the market are in compliance

| Brand \ Ingredient | Alfalfa | Grass meal | Maize | Wheat bran | Wheat pollards | Wheat middlings | Triticale | Barley | Barley distillers dried grains | Barley straw | Sunflower meal | Sunflower | Sunflower hulls | Dehulled soybean meal | Soybean meal | Soya | Soy hulls | Soy lecithin | Peas | Carob pulp | Carob seed husk | Carob seed meal | Grape pips extracted | Rapeseed | Sugar beet pulp | Molasses | Calcium carbonate | Sodium chloride | Sodium bicarbonate | Monodicalcium phosphate | Dicalcium phosphate | Calcium phosphate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Local 1 | x | | | x | x | | | x | | | | x | | | x | | | | x | | | | | x | | x | x | | | | | |
| Import 1 | x | | x | | | x | | x | x | x | x | x | | x | | | | x | | | | | x | | x | | x | x | | | | |
| Import 2 | x | | | x | | | | x | | | | | x | | | | | | | x | | | | | x | x | x | x | x | | | |
| Import 3 | x | x | | x | | | | | | | x | | | | | | | | | | x | x | | | | x | x | | | | | |

**Table 3:** Ingredients used in different brands of weaning rabbit feeds.

with the feed safety requirements as per Regulation of the European Commission (EC) No 178/2002. From an analytical point of view, all feeds (both locally manufactured or imported) trace back to the fact that their formulations were developed by expert nutritionists on an in-house basis, or provided by the pre-mix suppliers. At the time of the survey, the various types of locally manufactured feed formulations as well as imported ones on the local market are presented in Tables 2 to 9. Imported feeds are not procured in bulk, but rather arrive in pre-packed 25 kg bags, originating from ISO-certified feed mills in Italy and Spain. Results indicate that the local market is well supplied with properly formulated rabbit feed available. However, a point of contention exists among producers, whereby a perception exists that feed is lacking in terms of protein and fibre content, and should be improved.

Although none of the feed importers have qualified in-house personnel to provide professional advice on feeding, they nonetheless rely on the professional expertise available that is offered by their suppliers at the local level. The advice given by the importers to producers is to adopt a feeding regime during the weaning phase that provides a diet rich in fibre and low in protein, or a medicated feed that is gradually replaced by a grower/finisher feed at the latest three weeks before dispatching to market. The local feed mills recommend that newly weaned rabbits are started on adequate amounts of weaner feed that is gradually replaced by the grower-finisher feed and the amounts increased slowly until the daily feed consumption per rabbit reaches 120 grams. Most feed suppliers agreed that producers are using different types of feed according to its recommendations; however, this aspect mainly depends on the size of the farm; with small units generally tending to feed all the rabbits one type of formulation, while the larger ones are more inclined to adopt the practice of feeding the different animal classes according to their nutritional requirements and hence use multiple feed formulations.

**Feeding strategies** Most producers purchase feed from one supplier, while a few prefer to use feeds from different suppliers. The feeding strategies are not homogenous across the farms. Six producers use three different feed formulations to meet the requirements of the breeding doe, weaner and grower/finisher rabbits. The rest all implement a unique feeding programme. One uses four types of feed to meet the requirements of the doe, weaner, grower and finisher rabbit. Another uses two types of feed: one for the does and another feed used from weaning up to market. The last farm uses only one type of feed to cover all the life stages present on the farm. Only one producer referred to the feeding of the buck, and in this case, grower/finisher feed is being used. Several producers claim that the does are provided with loose hay to augment fibre consumption and to provide additional bedding during nest building. Medicated feed is used by the majority of producers during the weaning stage and results indicate that at times the recommended withdrawal period of medicated feed is not always respected.

**Rabbit health** The majority of producers claimed sufficient veterinary coverage, however, the other three stated that the advice received from the health professionals may at times lack consistency. On the other hand, the general consensus amongst professionals providing health-related services to commercial rabbitries felt that the sector is not adequately covered from the veterinary perspective.

The survey revealed that the local market is adequately supplied with the necessary vaccines and medications to

| Brand \ Ingredient | Alfalfa | Grass meal | Maize | Wheat bran | Wheat pollards | Wheat middlings | Triticale | Barley | Barley distillers dried grains | Barley straw | Sunflower meal | Sunflower | Sunflower hulls | Dehulled soybean meal | Soybean meal | Soya | Soy hulls | Soy lecithin | Peas | Carob pulp | Carob seed husk | Carob seed meal | Grape pips extracted | Rapeseed | Sugar beet pulp | Molasses | Calcium carbonate | Sodium chloride | Sodium bicarbonate | Monodicalcium phosphate | Dicalcium phosphate | Calcium phosphate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Local 1 | x | | | x | x | | | x | | | | x | | | x | | | | | | | | | | | | | | | | | x |
| Local 2 | x | | | x | | | | x | | | | | | | | x | | | | | | | | | | | x | | | | | |
| Local 3 | x | | | x | | | | x | | | x | | | | | | | | | x | | | | | x | x | x | x | | | x | |
| Import 1 | x | | x | | | x | | x | | x | x | | | | | | | | | | | | x | | x | x | x | x | | | | |
| Import 2 | x | x | | x | | | | | | | | | | | | | | | | | x | x | | | | x | x | | | | | |
| Import 3 | x | | | x | | | | x | | | | | x | | | | | | | x | | | | | x | x | x | x | x | | | |

**Table 4:** Ingredients used in different brands of grower/finisher rabbit feeds.

satisfy the requirements of the sector. Table 10 presents a list of available pharmacological products registered for use on rabbits at the time of the survey. All producers agreed on the accessibility of pharmacological products whenever required. However, although the required pharmacological products are available, the survey has indicated that there is a lack of locally available diagnostic services to facilitate the identification of the agent responsible for a particular morbidity.

An overview of the most common on-farm diseases identified by the various interviewees is listed in Table 11.

**Reproduction efficiency** All producers observed that conception rates are generally better during the November to April window (when ambient temperatures are cool) when compared to the rate of successful copulations during the May to October period (when ambient temperatures fluctuate between warm and hot). Hence, producers contend that the main constraint related to rabbit fertility is the effect of seasonality.

**Production genetics** There are no specialised registered rabbitries that supply hybrid breeding stock to commercial rabbit meat producers. At the time of this survey, only one local agent was involved in the importation of genetic stock from the renowned French company HYLA which has a proven track record of reliable supply of good quality genetic lines having superior maternal and paternal genetic merit.

On the other hand, the producers claimed that the breeding stock is procured either through importations from France and Italy, or by sourcing in-house through an on-farm selection taking into consideration size, production performance and meat production. The producers claim that the main rabbit hybrid lines found on farms are HYLA and Martini, while others use pure breeds of California and Cheeker giants for the paternal line and pure breeds of New Zealand White for the dam line.

One producer claims to have an on-farm selection programme using stock from various sources (HYLA, Martini and Grimaud Frères) imported over the last 30 years to develop a rabbit type with better conformation and a higher capacity to adapt to local conditions. However, there are no qualified livestock geneticists on the farm to direct, develop and implement this genetic selection programme.

## 4 Discussion

**Malta's isolation from mainland Europe** Malta's small agricultural area within the semi-arid climatic conditions cannot produce the grains and roughage required to sustain the local livestock sector, hence, livestock feeding is heavily dependent on the importation of cereals and roughage together with vitamin/mineral pre-mix. However, the fact that Malta is geographically separated from mainland Europe crates two constraint aspects: 1) the sector is highly vulnerable to market fluctuations abroad and 2) the logistics of continuous reliable supply. As a rule of thumb, feed costs cover around 75% of production costs; however, in Malta's case, importation has additional expenses. Similarly, the procurement of equipment, including cages with the associated paraphernalia, to the procurement of new stock for improved genetics are also burdened with additional costs. This creates a significant disadvantage when compared to the European counterparts, and in order to offset these extra costs and remain

| Brand \ Ingredient | Alfalfa | Grass meal | Maize | Wheat bran | Wheat pollards | Wheat middlings | Triticale | Barley | Barley distillers dried grains | Barley straw | Sunflower meal | Sunflower | Sunflower hulls | Dehulled soybean meal | Soybean meal | Soya | Soy hulls | Soy lecithin | Peas | Carob pulp | Carob seed husk | Carob seed meal | Grape pips extracted | Rapeseed | Sugar beet pulp | Molasses | Calcium carbonate | Sodium chloride | Sodium bicarbonate | Monodicalcium phosphate | Dicalcium phosphate | Calcium phosphate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Local 4 | x | | x | | x | | | x | | | | x | | | x | | x | | | | | | | | x | | x | x | | | | |
| Local 1 | x | | | x | x | | | x | | | | x | | | | | | | | | | | | | | | | | | | | x |
| Import 1 | x | | x | | | x | | x | | | x | | | x | | | | | | | | | x | | x | | x | x | | | | |
| Import 2 | x | | | x | | | | x | | | | | x | x | | | | | | x | | | | | x | x | x | x | | | | |

**Table 5:** Ingredients used in different brands of complete rabbit feeds.

competitive, the local sector has to strive for excellence with regards to production efficiency.

**Stakeholder knowledge and advisory services** Through this study, it emerged that there is a significant lack of knowledge amongst the majority of stakeholders who are active within the Maltese commercial rabbit sector. The majority of producers came across as having weak technical knowledge; indeed, they implement antiquated management practices based on amateurish hands-on experience rather than practices backed by scientific principles. This situation is very different from what De Battista (1985) reported; in that the majority of rabbit producers at the time were aware of the basic principles of rabbit husbandry and stockmanship due to the dissemination efforts of the Rabbit Breeders Association to educate their members.

Producers' perceptions on how to increase on-farm animal welfare were limited to aspects of controlled temperature and humidity within the production barn, having larger cages, allowing for longer intervals between mating, and any other actions which in their opinion reduce stress on rabbits. However, what has emerged from this study is the fact that a third of the producers lack sufficient knowledge pertaining to on-farm animal welfare. These producers are not aware of the five freedoms of animal welfare (basic animal welfare principles) and therefore, they may be unable to identify poor animal welfare conditions on-farm or such problems may be identified when it is too late. The lack of knowledge on this subject may be linked to the questionable absence of animal welfare issues reported on their farms, especially considering their lack of knowledge of basic animal welfare freedoms. The fact that a significant number claimed not to be aware of basic animal welfare principles can only mean that they are not well-read even in the most basic aspects of management, and operate within a bubble, oblivious of current developments in the sector.

Results also indicated that a full array of rabbit feed formulations, whether imported or manufactured locally, are available on the market to meet the recommended nutritional requirements of the full cycle of rabbit production. However, producers implement feeding programmes that they perceive to be adequate, ignoring recommendations from professionals advising the use of specific feed at different parts of the production cycle. Indeed, medicated feed intended for weaners is at times fed throughout the growing/finishing stages, and the withdrawal periods of medicated feeds are not respected. On the other hand, some feed suppliers act on a purely commission basis, meaning that they are middlemen between overseas feed manufacturers and the local rabbit producer. Hence, their sole interest is the selling of feed without being knowledgeable on aspects of rabbit nutrition, thereby being incapable of recommending the use of the various formulations that they supply. The same applies to local feed mills that manufacture rabbit feed on formulations supplied by the suppliers of the pre-mixes being used without actually having an in-house animal nutritionist.

In the absence of a local structured advisory service offering advice and recommendations on livestock production management practices, rabbit producers seek advice from veterinary health professionals, word of mouth, online information, and fancy rabbit breeder associations. Nonetheless, the ultimate understanding of the acquired advice and recommendations pivots on the depth of understanding by the actual producer. A case in point is a recent episode where a lower VHD vaccination dose was being administered by the producers with the repercussion

| Brand | Directions for use | Price | Crude protein | Crude fibre | Crude oils & fats | Crude ash | Calcium | Sodium | Phosphorous | Coccidiostats & Histomonostats |
|---|---|---|---|---|---|---|---|---|---|---|
| Local 1 | Complete feed, can be also used for breeding does with kits | €9.75 | 16.8% | 15.5% | 5.0% | 7% | 1.0% | | 0.57% | 1mg/kg |
| Local 1 | Breeding does and lactating breeding does | €10.85 | 17.5% | 14.4% | 6.0% | 7.2% | 1.0% | | 0.6% | 1mg/kg |
| Local 2 | Last period of gestation and during lactation | €10.50 | 14.3% | 11.5% | 3.79% | | | | | |
| Local 3 | Breeding does and pregnant does | €10.00 | 16.5% | 16.8% | 2.8% | 8.5% | 14 g/kg | 1.5 g/kg | 6.0 g/kg | 66mg/kg |
| Import 1 | Breeding does | €10.80 | 16.92% | 15.44% | 3.96% | 7.26% | 1.09% | 0.2% | 0.71% | 66mg/kg |
| Import 2 | Breeding rabbits | €10.40 | 18.0% | 15.0% | 4.5% | 9% | 1.10% | 0.20% | 0.70% | 66mg/kg |
| Import 3 | Breeding rabbits | €10.35 | 14.5% | 15.0% | 3.3% | 6.5% | 1.01% | 0.08% | 0.63% | 1mg/kg |

**Table 6:** Analytical analysis of breeding doe feeds.

that these farms suffered significant losses.

**Climatic constraints** The climate of the Maltese Islands can be described as being a typically Mediterranean one, characterised by mild, wet winters and hot, dry summers. Nonetheless, the archipelago receives a significant amount of sunshine all year round (mean 8.3 hours of bright sunshine per day), peaking in solar radiation in summer registering almost 8 kWh/m$^2$/day, while dropping in winter to a minimum of 2.5 kWh/m$^2$/day (Schembri, 1997). On encountering a surface, the radiation may be reflected, transmitted or absorbed. If absorbed, the surface will heat up and act as a heat collector. Within this context, the roofs and walls of buildings that directly receive this solar radiation act as an absorbent material that collects and accumulates heat energy, which is later released into the inside of the production barns. The insulation of farm buildings is critical to maintain internal temperature controls. In fact, McNitt et al. (2013) recommend that both the walls and ceilings of an environmentally controlled building should be insulated. An insulated building is necessary to complement the action of cooling systems and to minimise radiation of heat from the roof into the rabbitry.

Producers have indicated that they are experiencing lower production performances during the summer months. The seasonality in performance is linked to the variations in the internal ambient barn temperature. Hence, despite some producers claiming that their barns are insulated, in reality, they all face problems related to heat stress. This situation leads one to assume that neither producers nor their consulting building engineers have adequate knowledge on the construction of suitable livestock housing, much less the technology required to maintain the internal barn temperatures within the species-specific thermoneutral zone, also known as the comfort zone. Hence, none of the barns on the farms included in this survey can be considered as being adequately insulated or equipped with cooling systems.

The ideal environment in a rabbit housing unit is about 15°C to 20°C with around 50% relative humidity (McNitt et al., 2013). Marai and Rashwan (2004) reported that when ambient temperatures surpass the 30°C mark, in an attempt to reduce environmental heat load, rabbits adapt specific behaviour strategies associated with efforts to dissipate body heat. These behaviours include: increasing respiration rates, stretching to expose a higher body surface area to increase heat loss by radiation and convection, and the orientation of the ears away from the body. Heat stress is also associated with a reduction in feed intake and overall farm productivity

The reproduction efficiency of the doe decreases when the internal barn temperature falls outside the 15°C to 20°C window (Liang et al., 2022). When this ambient temperature is exceeded, does are prone to experience heat stress, which will consequently have a negative effect on their reproductive performance (Marco-Jiménez et al., 2017). In particular, heat stress impacts conception rates, embryonic development, litter size, milk production (Hen & Wang, 2004), and litter weights (Marai et al., 2002). Reduced oestrogen secretion resulting in irregular oestrus, and complications in egg cell fertilisation were reported by Garcia and Argente (2017). During episodes of heat stress, larger quantities of blood are diverted to the extremities in an attempt to lose heat. In the case of pregnant does this redirection reduces the volume of blood nourishing the uterus and umbilical cord, causing insufficient supply to the developing embryos (Marco-Jiménez et al., 2017); thus, embryo survival is jeopardised and may lead to a high in-uterine mortality and abortions (Song et al., 2006). The results obtained by the various studies consulted above are in agreement with a local study con-

| Brand | Directions for use | Price | Crude protein | Crude fibre | Crude oils & fats | Crude ash | Calcium | Sodium | Phosphorous | Coccidiostats & Histomonostats |
|---|---|---|---|---|---|---|---|---|---|---|
| Local 1 | Weaning stage | €10.00 | 16.5% | 17.0% | 5.5% | 6.9% | 0.8% | | 0.6% | |
| Import 1 | Weaning stage | €11.00 | 14.44% | 19.37% | 3.61% | 7.41% | 1.81% | 0.2% | 9.45% | 66mg/kg |
| Import 2 | Weaning stage | €10.20 | 16.5% | 17.5% | 3.2% | 8.5% | 1.2% | 0.20% | 0.60% | 66mg/kg |
| Import 3 | Weaning stage | €10.45 | 14.0% | 14.2% | 3.6% | 5.5% | 0.62% | 0.06% | 0.61% | 1mg/kg |

**Table 7:** Analytical analysis of weaning rabbit feeds.

ducted by Sammut (2008). The latter study found that the breeding stock kept in housing equipped with cooling systems performed better than others kept in barns not equipped without such facilities

Notably, rabbit bucks kept under heat stress conditions exhibit suppression of testosterone secretion, libido, and spermatogenesis. Liang et al. (2022) reported that bucks are more sensitive to high temperatures when compared to does. The synthesis and secretion of hypothalamic gonadotropin-releasing hormone (GnRH) are reduced under high temperatures, which significantly affects the function of the testis and decreases semen quality (viability), thus affecting bucks' reproductive performance (Daader et al., 2016).

The fact that all producers commented on experiencing a decrease in reproductive performance indicates that most likely, the production barns are not adequately insulated and thus, the extreme outside temperatures are causing heat stress on the animals. Although the general situation is that the breeding stock and progeny are kept in the same barn, surprisingly none of the producers commented on the effect of heat stress on the growth parameters of the growing/finishing market rabbits. The literature review retrieved a previous study published in a peer-reviewed journal that was conducted locally on the effect of heat stress on growing/finishing rabbits Marongiu et al. (2006) investigated the effects of high ambient temperatures in terms of water-to-feed ratio and daily weight gain in two groups of growing/finishing rabbits from the ages of 6 to 12 weeks. One group was kept outside under a canopy with ambient temperatures during the test period varying from 35-46°C, while the other group was kept indoors in an environment-controlled barn with a constant temperature of 20°C. The results indicated that the rabbits kept within the comfort zone had higher FCR and higher average daily weight gains.

**Rabbitry design and adherence with the Maltese Code of Good Agricultural Practice** Barn facilities found on farms are not homogenous and vary from purposely built facilities to the modification of older structures that were previously used for other livestock, such as swine or poultry. Due to space limitations, farm designs tend to maximise the usability of available areas, often resulting in cramped conditions. Consequently, most farms have only one production barn and no feed silos are present.

Although some of the producers declared the presence of a quarantine/isolation area, in reality, this facility may be a room located within the main production barn. The fact that the quarantine/isolation space is within the same barn as the production stock supports the previous reference to the producers' lack of knowledge on rabbit production and in this case, also with regard to biosecurity aspects and rabbit health. Quarantine procedures usually include a designated area to receive procured replacement stock or to act as a sick bay for rabbits that need individual attention. Ideally, this quarantine facility should be located away from the barn housing the main stock with a separate entrance to comply with the European Animal Health Law Regulation (EU) 2016/429.

Since no on-farm feed silos are present, producers have no choice but to procure feed in 25kg bags at a higher cost per ton (McNitt et al., 2013) On-farm silos would not only allow for lower feed costs but would also store feed in a more manageable manner and enhances biosecurity measures with regards to contamination from pests and rodents.

Only one farm claimed to have an automated feeding system installed, whilst the rest resort to manual feeding incurring higher labour costs. Although it is more work intensive, by default, manual feeding obliges the producers to inspect every cage as they move down the alley.

Locally manufactured rabbit cages are mostly aimed to meet the demands of very small-scale backyard producers. Commercial farms usually opt for purchasing imported cages from renowned companies that specialise in rabbit cages sourced from European companies that manufacture cages according to European standards. All cages are equipped with all the necessary compartments for feeding, drinking, and nesting, and are constructed out of wire mesh and supported on stainless-steel stands. This type of cage material facilitates the cleaning and disinfection of cages during the cleaning process. Although the same manufacturing companies provide automated feeders to complement their cages, only one has opted for them. On the other hand, all farms have automated drinking

| Brand | Directions for use | Price | Crude protein | Crude fibre | Crude oils & fats | Crude ash | Calcium | Sodium | Phosphorous | Coccidiostats & Histomonostats |
|---|---|---|---|---|---|---|---|---|---|---|
| Local 1 | Market rabbits > 7 weeks of age | €9.80 | 16.0% | 17.8% | 5.0% | 6.5% | 1.0% | | 0.4% | |
| Local 2 | Growing rabbits | €9.80 | 13.8% | 16.8% | 3.05% | | | | | |
| Local 3 | Growing rabbits | €9.75 | 16.5% | 15.3% | 2.5% | 8.1% | 10.0 g/kg | 1.5 g/kg | 6.0 g/kg | 60mg/kg |
| Import 1 | Fattening rabbits | €10.20 | 14.11% | 18.01% | 2.71% | 7.83% | 1.13% | 0.2% | 0.55% | |
| Import 2 | Fattening rabbits | €10.00 | 13.4% | 14.10% | 3.3% | 5.6% | 0.65% | 0.06% | 0.60% | 1mg/kg |
| Import 3 | Fattening rabbits | €11.20 | 16.5% | 16.0% | 3.5% | 8% | 1.10% | 0.20% | 0.60% | |

**Table 8:** Analytical analysis of grower/finisher rabbit feeds.

water systems: water is delivered through a nipple system where water flows through gravity from overhead tanks. The majority of farms are equipped with different cage sizes and designs to meet the requirements of various life stages (from kindling to market rabbits) as well as to accommodate the projected rabbit population inventory.

The most frequent cage designs found on-farm are flat deck, a two-tiered Californian style, and a combination of both. In this regard, one needs to refer to the latest European Food Safety Authority (EFSA) published opinion on the health and welfare of farmed rabbits in 2020. This opinion states that from an animal welfare perspective, the commercial conventional wire cages ranked last when compared to other rearing designs. As a follow-up to this, the European Commission is putting forward a legislative proposal to ban all cages for a number of farmed animals, including rabbits. If approved, this legislation will most likely experience resistance from the local producers. All the interviewed producers expressed their resentment towards this proposal and are of the opinion that loose farming would not be economically feasible on a commercial scale level. They anticipate that loose housing systems will give rise to aggressive behaviour due to territorial instincts and to secure access to feed. They also voiced their concern about the increased predisposition to disease and the challenging conditions of maintaining adequate hygiene and health controls. Furthermore, the demand for a larger area per animal in a reality where space is scarce makes this proposal redundant. On the same line of thought, organic rabbit production in Malta is a non-starter.

All livestock operations have to comply with the relevant measures stipulated in the Maltese Code of Good Agricultural Practice. The measures that relate to rabbitries were identified and each of the measures is discussed in light of the results from the survey.

(A) Have careful preparation, storage and transport of feed:
All farms abide by this measure, however, the absence of feed bins due to lack of space does not allow for the purchase of feed in bulk.

(B) Ventilation should always secure good indoor air quality for animal health and welfare without creating environmental hazards:
The majority affirmed that the farms are adequately equipped with ventilation systems, and thus are in compliance with this measure. However, upon further inquiry, producers do not have a good grasp of the scientific principles behind ventilation. In their view, ventilation encompasses the installation of extractor fans only without taking into account the rate of air exchanges in the barn.

(C) Good artificial lighting should be secured in production areas:
Artificial lighting is to be provided if natural lighting is not sufficient. All of the interviewed producers indicated that their production barns have high-level windows to let in natural daylight. In addition, some of the producers claim to have in place a lighting programme to deliver a 16-hour light followed by a dark period of 8 hours.

(D) Manure to be stored outside in proper storage facilities:
The results indicate that mechanical manure handling systems are present on larger farms, while the smaller ones rely on the manual removal of manure. In all cases, a purposely built manure clamp is present on-farm. These practices and structures dedicated to the safe storage of manure are compliant with all the measures recommended in this respect by COGAP.

(E) Solid and liquid manure has to be stored in covered clamps from the 15th of October to the 15th of March:
Manure is kept on-farm during this timeframe due to the rainy season and to prevent excessive nutrient runoff and leaching. The producers participating in this study adhere to this measure. In accordance with another measure, manure is spread on land between the 16th of March to the 14th of October.

(F) The producer and/or contractor has to keep records

| Brand | Directions for use | Price | Crude protein | Crude fibre | Crude oils & fats | Crude ash | Calcium | Sodium | Phosphorous | Coccidiostats & Histomonostats |
|---|---|---|---|---|---|---|---|---|---|---|
| Local 4 | Complete feed. Feed to breeding and fattening rabbits | €9.85 | 16.5% | 17.5% | 2.5% | 7.5% | 1.0% | | 0.5% | |
| Local 1 | Complete feed for all stages of productions | €9.00 | 16.0% | 15.9% | 2.0% | 6.7% | 1.0% | | 0.6% | |
| Import 1 | Complete feed for all stages of productions | €10.50 | 17.02% | 15.91 % | 3.0% | 8.38% | 1.44 % | 0.2 % | 0.65 % | 0.02mg/kg |
| Import 2 | Complete feed for all stages of productions | €10.00 | 16.5% | 16.5% | 2.8% | 8% | 1.2 % | 0.1 % | 0.60 % | 66mg/kg |

**Table 9:** Analytical analysis of complete rabbit feeds.

of manure transports:
Producers are obliged by the Nitrates Directive Act to keep a record of when and how much manure is removed and where it is being spread.

**Biosecurity** In the European Animal Health Law Regulation of the European Union (EU) 2016/429, biosecurity is defined as: 'the sum of management and physical measures designed to reduce the risk of the introduction, development, and spread of diseases to, from and within: (a) an animal population, or (b) an establishment, zone, compartment, means of transport or any other facilities, premises or location'.

Results indicated that biosecurity measures on local rabbit farms are of poor standard since the majority of producers just implement a basic pest control programme. Producers lack sufficient training and knowledge on the subject, and they underestimate the importance of implementing on-farm biosecurity measures. In some cases, the most basic biosecurity measures are lacking, such as facilities for personal hygiene such as an anteroom, toilets, and showers, and the lack of a rabbit quarantine/isolation area. It is of utmost importance that all farm personnel's visits to the rabbit farm should begin in an anteroom, where visitors and staff can put on farm-specific clothing and footwear and wash their hands appropriately (Neumann & Hall, 2019). This further decreases the possibility of pathogen transmission. The presence of a quarantine/isolation holding facility is mandatory as per European Animal Health Law Regulation (EU) 2016/429. Sick rabbits that have been potentially exposed to an infectious or contagious disease should be isolated from the stock present on the farm. Purchased new stock should also be kept separate from the rest of the stock present on the farm for at least two weeks. The mentioned precaution may prevent the spread of diseases on rabbit farms in case such diseases are at an incubation stage at the time of purchase (McNitt et al., 2013).

Furthermore, risks from pathogens being carried over by wind from neighbouring farms are also of concern. This is of particular interest to Malta since only 8% of the days are considered to be calm. The predominant wind is the North-western, which on average blows on 19% of windy days (Schembri, 1997). The other winds are all nearly equally represented. Given that Malta is a relatively small island, disease transmission between one farm and another can in theory be a threat, as highlighted by health professionals. Indeed, Ellwanger and Chies's (2018) study revealed that wind must also be considered a crucial factor in the transmission of various diseases since it can modulate the dynamics of different vectors and pathogens. The Maltese Code of Good Agricultural Practice also includes biosecurity measures that have to be adhered to. The measures that relate to rabbitries were identified and each of the measures is discussed in light of the results from the survey.

(A) A vehicle disinfection pit is recommended to be present at the entrance of the farm:
Results indicated that the majority of producers do not have a disinfectant pit and hence are not compliant with this measure.

(B) Good animal welfare and health conditions ensure good animal performance:
The fact that all the producers observe a decrease in performance during the summer months can only imply that the animals are under a constant state of heat stress during this period. Furthermore, as already commented previously, locating a quarantine/isolation facility within the same production barn defeats its purpose. This further confirms the producers' lack of understanding of basic concepts related to animal welfare and animal health, irrespective of them claiming otherwise

**Rabbit health** The survey revealed that the local market is well stocked with pharmaceutical products to address all of the ailments faced by the commercial rabbit

| VET number | Name of veterinary medicinal product | Dosage form | Active ingredients |
|---|---|---|---|
| Vaccines | | | |
| VET 467 | Toxipra plus | Vaccine | Costridium toxoids and anaculture |
| VET 56 | Cunivax Mixoma | Vaccine | Live-attenuated Borghi strain of rabbit Myxomatosis virus |
| VET 117 | Cunivax P.B. | Vaccine | Pasteurella multocida 15 bn, Bordetella bronchoseptica 15 bn |
| VET 142 | Cunipravac -RHD | Vaccine | Virus RHD strain 3116-AP |
| VET 145 | Mixohipra-H | Vaccine | Live attenuated Sanarelli virus strain VMI |
| VET 282 | Castorex | Vaccine | RHD RHDV PHB 98 - min. 1PD 90 |
| VET 451 | Castomix | Vaccine | Attenuated Myxomatosis virus . MAV; inactivated RHD virus, s. PHB 98 |
| VMA 86 | Castorex Neo | Vaccine | Inactivated Rabbit Haemorrhage Disease Virus type 2, Strain RHDV2 F/12 B |
| CA 71 | Nobivac Myxo-RHD PLUS lyophilisate and solvent for suspension for injection for rabbits | Vaccine | Live myxoma vectored RHD virus strain 009, Live myxoma vectored RHD virus strain MK1899 |
| Antibiotics | | | |
| VET 416 | Trimetoprim-Sulfadimetossina | Oral solution | Trimethoprim 40mg/g; Sulfadimethoxine 200mg/g |
| VET 829 | Trisulmix liquide | Oral solution | Sulphadimethoxine sodium 186.7mg/ml; Trimethoprim 40.0mg/ml |
| VET 346 | Ganadexil Enrofloxacino oral solution | Oral solution for use in drinking water | Enrofloxacin 100mg/ml |
| VET 370 | Bacipremix | Medicated feed premix | Bacitracin 0.05g/g |
| VET 415 | Ossitetraciclina 20% | Powder for oral solution | Oxytetracycline 200mg/g |
| VMA 81 | Apravet 552 IU/mg | Powder for use in drinking water/milk | Apramycin (as Apramycin sulfate) 552 IU |
| VET 703 | Paromomicina huvepharma 200g/kg | Medicated premix | Paromomycin 200g/kg |
| VET 700 | Bacivet S 4200 IU/g | Powder for use in drinking water | Bacitracin zinc 4200 IU/g |
| VET 882 | Isathal 10mg/g eye drops suspension for dogs, cats and rabbits | Eye drops suspension | Fusidic acid 10mg |
| VET 31 | Fatroximin spray | Spray | Rifaximin 0.5g /142g |
| Anti-parasites | | | |
| VET 308 | Aca Cerulen R 300ml | Ear spray | Chlorocresol 1.2g/100ml, Pyrethrum 1.2g/100ml, Piperonyl butoxide 3g/100ml |
| Hormones | | | |
| VET 694 | Receptal | Solution for injection | Buserelin acetate 0.004mg/ml |
| VET 976 | Gabbrostim, 2 mg/ml injectable solution for cattle, pigs, horses and rabbits | Solution for injection | Alfaprostol 2mg/ml |

**Table 10:** List of available pharmacological products grouped according to type.

| Viral Diseases | Bacterial Diseases | Fungal Diseases | Parasitic Diseases |
|---|---|---|---|
| VHD<br>Myxomatosis | Enterotoxaemia<br>Pasteurellosis<br>Mastitis | Dermatophytosis | Sarcoptic mange |

**Table 11:** The most commonly/prevalent diseases occurring on commercial farms.

sector in Malta, as presented in Table 10. These products are readily available from various veterinary pharmacies, while some pet shops provide over-the-counter products. A common comment expressed by all health professionals is the lack of specialised veterinarians in rabbit health and the lack of diagnostic laboratory facilities. On the other hand, the producers believe there are sufficient veterinarians to service the sector. This may indicate that the few veterinarians who work within the sector provide constant services to the producers' satisfaction.

The most commonly occurring diseases on commercial rabbit farms in Malta as reported by the health professionals and the producers are presented in Table 11.

Despite the substantial advancements made in the fields of genetics, feed, and management, the higher productivity, the high selection of breeds, and their crosses made the presence of disease on-farm still inevitable (Espinosa et al., 2020). Animal diseases have an important effect on animal productivity and welfare (Grace et al., 2015). Numerous studies have been carried out, analysing the monetary costs of diseases including the outcome of mortality losses, reduced productivity and control expenses (Grace et al., 2015). Solans et al. (2019) reported that in many EU countries, enteric problems are considered to be the main cause of monetary losses on meat rabbit farms.

Subsidiary Legislation 437.47 of the Maltese Law obliges all livestock producers to have an animal health control programme in place and implemented under the responsibility of a professional registered with the Veterinary Surgeons Council. The first lesson taught in animal health management is that prevention is better than cure; however, the results of this survey indicated that irrespective of the requirements of the legislation, the prevention aspect, usually implemented through the application of a proper on farm biosecurity programme is lacking. This calls for urgent action to be taken by the competent bodies to offer training and instruction to producers in order to improve their awareness of the importance of implementing a proper biosecurity programme to cover the whole farm. Morbidity has a huge financial implication since animals' compromise production while they continue to consume feed.

As described in the section of biosecurity, farms have

| Farm | Conception | Kindling | Weaning | Efficiency |
|---|---|---|---|---|
| A | 70 % | 85 % | 90 % | 53.6 % |
| B | 75 % | 95 % | 95 % | 67.7 % |
| C | 50 % | 50 % | 50 % | 12.5 % |
| D | 90 % | 95 % | 90 % | 77 % |
| E | 90 % | 95 % | 90 % | 77 % |
| F | 80 % | 80 % | 85 % | 54.4 % |
| G | 85 % | 80 % | 85 % | 57.8 % |
| H | 70 % | 70 % | 70 % | 34.3 % |
| I | 95 % | 95 % | 95 % | 85.7 % |

**Table 12:** Conception, kindling, weaning rates and conception to weaning cycle efficiency ranked according to farm size. Efficiency Formula = 100 x (Conception % / 100) x (Kindling % / 100) x (Weaning % / 100)

severe limitations due to space and have to make do with what is available and maximise its use. Thus, the most common production system is what is known as a continuous cycle within the same barn, as opposed to the recommendations to practise the all-in/all-out principle. Thus, cleaning and disinfection protocols between different production cycles cannot be carried out (Huneau-Salaün et al., 2015). In this scenario, the on-farm biosecurity measures that need to be implemented have to be even more robust and complemented with a purposely designed animal health control programme that would include preventive measures such as vaccination programmes and sanitisation measures.

**Feeds and feeding strategies** As already alluded to previously, the supply of rabbit feed is susceptible to the volatility of international markets. The results indicated that the local market is well supplied with a variety of feed brands, each having a number of different feed formulations. The brands can be classified into two groups: one that encompasses locally manufactured feed, while the other includes suppliers that import balanced feed from abroad. Within these various entities involved in the supply of rabbit feed, only one has an in-house nutritionist. Hence, the majority of entities supplying rabbit feed lack the basic knowledge on rabbit nutrition and thus are not in a position to provide proper advice to their clients. Thus, although the market is flooded with a variety of differently formulated rabbit feed, producers do not necessarily implement a feeding programme that would maximise feed efficiency.

Producers commented on the fact that since feed needs to be imported, there may be instances when availability is inconsistent, and the abrupt switching to other brands or types is claimed to result in metabolic problems leading to

| Category | Quantity | Diet |
|---|---|---|
| Young Does | | |
| Early mating 15-16 weeks | Ad libitum | Fatteners |
| Late mating 17-20 weeks | Restricted | Fatteners or specific rearing diets |
| Does | | |
| Late gestation | Ad libitum | Lactation |
| Lactation | Ad libitum | Lactation |
| | Kits < 3 weeks | Lactation |
| | Kits > 3 weeks | Weaning |
| In pre-gestation cages | Restricted | Fatteners |
| Males | | |
| Young until 18 weeks | Ad libitum | Fatteners |
| Adult | Restricted | Fatteners |
| Weaned rabbits | | |
| 4-9 weeks | Restricted | Fatteners |
| 8-11 weeks | Ad libitum | Fatteners / Finishing |

**Table 13:** Feeding strategies for commercial rabbit meat production.

diarrhoea. In addition, they also commented that in their opinion, the quality of the feed found on the local market should be improved, especially in terms of protein and fibre content. Upon comparing the analytical analysis of the feeds found on the local market (Tables 6 and 8) with the recommendations of de Blas and Mateos (2020), it is evident that this claim is unfounded; however, it reinforces the fact that producers lack basic knowledge of feed and rabbit nutrition.

The survey has indicated that the weaning stage is a very delicate phase that needs particular attention. Newly weaned rabbits are highly susceptible to morbidity and mortality; hence, it is a crucial stage that reflects strongly on the overall profitability of the farm. Weaning is a very delicate stage regardless of whether the kits are physically removed from the doe or if the doe is removed since in both cases, the newly weaned rabbits have to endure the stress of transitioning from a liquid feed to a solid diet. Feed suppliers recommend to producers that in order to maximise growth efficiency, rabbits need to be given the appropriate feed at the right age, offered ad libitum with a constant supply of good quality water and follow good biosecurity practices. These recommendations are in line with the feeding strategies suggested by Maertens (2020), which are presented in Table 13.

With the gradual shift by the producers from a generic diet fed across the stock inventory to a feeding strategy that involves a number of specifically formulated diets, the feed suppliers commented that over the last 30 years, they have experienced a higher request for larger quantities and better-formulated rabbit feed to meet the producers' demand. The results suggested that the feeding strategies differ across farms and vary from the better ones employing precision feeding by using 4 types of formulations, to other farms that give just one type of feed across the board. This obviously will result in different production results across the farms. Rabbits at various stages throughout their life cycle have different nutritional requirements; hence, the use of unified will create instances where the feed oversupplies the required nutrients and other instances where the feed does not meet the nutritional requirements. Therefore, the feeding of a single formulation throughout the farm could potentially lead to consequences in aspects of growth, productivity, digestive functions, and ultimately the overall profitability of the farm.

The effects of heat stress on rabbit physiology have already been discussed in the previous section. Rabbits exposed to temperatures higher than their comfort zone require specialised diet formulations taking into account this environmental stressor. Such formulations are not currently available on the local market.

Of particular interest is the fact that in some cases, the text on the labelling of the imported feed is in a foreign language. Apart from not being in line with Article 14 point 1 of Regulation (EC) 767/2009, this would only lead to confusion among the producers. The directions for use as printed on the labels are often too small to comprehend or misinterpreted and hence applied incorrectly.

Although a wide spectrum of feed formulations is present on the local market, this study has identified the existence of several challenges related to feed handling and feeding. These include: the storing of feed in bags in environments that are hot and humid, which may lead to the rapid deterioration in feed quality; the inconsistency of feed supply from suppliers; and inappropriate feeding strategies (including overfeeding), which may lead to episodes of diarrhoea.

**Reproduction efficiency** The reproductive efficiencies of the interviewed farms are indicated in Table 12, which presents the results according to farm size. Based on the declarations made by the producers, conception and kindling fall within the 70% to 95% success rate; however, one farm reported significantly lower conception and kindling rates. The discrepancy in these success rates can be due to a variety of reasons. Issues related to heat stress and the practice of improper feeding strategies have already

been discussed. Other issues identified in this study that may contribute towards reducing the fertility rate will be discussed hereunder.

In a number of farms involved in this study, the stud bucks are housed in the same barn together with the breeding does and their progeny. This means that the bucks are subjected to the same light programs as the does, usually consisting of 16 hours of light and 8 hours of dark. Boiti et al. (2005) claimed that bucks exposed to a constant lighting stimulus under a programme of 16 hours of light affects the hypothalamus-pituitary axis which releases hormones, thus increasing spermatozoa production. In the case where bucks are not housed within the main production barn, they are usually exposed to natural day length. As reported by Theau-Clément et al. (1990), Mirabito et al. (1994), and Gerencsér et al. (2008) the conception rate of does exposed to 16 hours of light 8 days before insemination increases by 10%.

The length of breeding cycles, also known as the period between two successive copulations, is an important parameter to take into consideration. Most of the producers reported that the most common re-mating strategy follows a 51-day cycle. According to Mayer (2022), if the inter-litter time is too long, the does start accumulating fat and reducing fertility. However, if it is too short, they may become underweight and have a reduced receptivity to the buck and fertility. Azard (2006) reported that the 42-day breeding cycle is the most common cycle used in Europe. Furthermore, Gerencser et al. (2011) compared the 42 and 56-day breeding cycles and noticed that the amount of kits/doe/year of the 42-day breeding cycle was higher by 19% to 23% when compared to the 56-day breeding cycle.

Similarly, to the case discussed above regarding the availability of various pharmaceutical products to prevent and cure ailments, producers have easy access to pharmaceutical preparations and associate paraphernalia to synchronise the oestrus of does and to administer AI. Most of the interviewed producers practise AI using semen from stud bucks present on farm while the others prefer to use natural mating using the on-farm bucks. Another option is to procure semen from a local source specialising in the supply of fresh semen from imported high genetic merit bucks. This supplier indicated the largest demand for fresh semen is from the backyard industry. The larger commercial farms prefer to purchase genetically superior bucks from abroad and practise on-farm AI. Shuji (2009) reported that AI is a more suitable mating practice for small and large commercial farms than natural copulation. Performance on farms using AI benefits in productivity parameters and access to superior genetics (Nassif & El-Sabrout, 2020). However, the AI procedure requires a high level of technical competence under aseptic conditions to ensure appropriate sanitisation to safeguard the health and well-being of the doe. Generally speaking, the procedure involves that a number of does are synchronised so as to be receptive for insemination on a particular day, thereby also serving as a means to pre-program kindling dates to fall with normal work days when operators are available to inspect the does.

Supplies to carry out AI and synchronisation procedures are very accessible and have a reasonable cost. The indicative prices for the purchasing of AI equipment and supplies for synchronisation are the following: single disposable pipettes cost €0.50 each; diluent including receptacle is €50 for 500 does; €35 for hormones per 100 does; and artificial vagina for €50. If semen is also purchased, this costs €0.50 for each insemination. Although one can easily access all the necessary apparatus to conduct AI, the fact remains that there is no training programme specialising in rabbit AI available.

**Production genetics** As alluded in the results, currently there are no local entities dedicated to the supply of genetically improved rabbits through a franchised agreement with internationally renowned breeding companies nor from entities dedicated to the local development of hybrid rabbits. One of the most important aspects of rabbit breeding is the selection of an ideal breed for meat production. De Battista (1985) reported that the Flemish Giant was the most popular breed in Malta during that time due to its genetic makeup, however, the importation of foreign genetics took the place of this breed by introducing the New Zealand white and the Californian that ranged as the most popular breeds in Malta. Recently, Busuttil (2005) reported that a Maltese rabbit breeder, the late Mr Joe Gauci Maistre, had claimed to have developed on his farm a hybrid line of white rabbits with brown eyes having superior meat production traits. This hybrid line is locally known as the Maltese Silver.

Today, breeding stock is imported, usually from Southern European countries (historically from Italy, France or Spain) where companies specialising in the selection and genetic improvement of rabbits exist. Producers identified 4 types of imported rabbits: the importation of F1 female day-old kits; the importation of juvenile grandparent stock on the dam line as well as for the paternal line; the importation of juvenile dam and sire F1 parent stock; and the importation of genetically superior bucks to supply semen for AI. The challenges faced when importing rabbits include remarkably high transportation costs, transport stress on the animals, and potential delayed delivery. Delays in consignments because of the suspension of shipping services between Sicily and Malta due to weather conditions cause disastrous effects on the stock since pro-

longed transit time in cargo conditions results in increased stress on the juvenile rabbits, which could also lead to higher-than-normal mortality rates.

Assuming that the issue of ferry suspension is only a rare occurrence, the Maltese producers are at par with their European counterparts with regard to access to high genetic merit rabbits. In fact, over the last 30 years, the commercial hybrids - HYLA, Martini and Grimaud Frères - have all been represented on local rabbit farms in varying amounts. Producers are also aware of the occurrence of hybrid vigour when crossbreeding two pure breeds. The results indicated that some producers utilise the California and Cheeker giant breeds as sires due to their carcass characteristics, while the New Zealand White females are used as does due to their excellent maternal characteristics. This cross-breeding scheme is in agreement with Szendro et al. (2012), who recommend the use of New Zealand White, California, and other medium-sized breeds as the best choice to improve reproductive or productive performance.

Genetics is a strong tool that can have a significant contribution towards overall farm efficiency. The use of hybrids and crossbreeding to capitalise on the vigour so as to produce robust parent stock has already been mentioned. Another aspect of genetics that none of the interviewed stakeholders made reference to is that carcass characteristics are highly heritable, and hence can easily be transmitted from parent to progeny. For example, the use of specialised bucks to produce offspring with heavier and meatier thighs to meet consumer demands was only mentioned by one producer.

The indicative prices for locally produced and imported F1 parent stock are the following: imported does of 10 weeks cost €35-€40 while bucks of 14 weeks cost €120-€140, and locally produced does/bucks at 5 weeks are sold for €12, with an increment of €1 per week.

## 5 Conclusion

It is evident that the rabbit meat sector is in urgent need to become organised within an administrative structure. Such a structure would represent the larger commercial farms as well as the small backyard operations that currently are considered ghost operations and are not captured in any official statistics or any official register held by competent authorities. When rabbit meat producers, irrespective of size, are given the opportunity to come together under an umbrella structure that will act on their behalf in negotiations with national competent authorities as well as to disseminate information to their members, the members would represent the majority of rabbit holdings and thus a quasi-accurate estimation of the size of the industry can be forecasted.

National statistics are at a loss in sizing this sector since according to Legal Notice 165 of 2011, operations with less than 50 does are exempt from the obligation to be registered with the competent authorities. Although backyard rabbit production is not captured in the national statistics, one could safely assume that this segment includes small rabbit units comprised of up to 10 does kept for home consumption (Attard et al., 2023). Hence, anyone who is keeping rabbits that falls within this category and is not a registered farmer escapes the system. This thriving backyard sector contributes significantly towards the total amount of locally produced rabbit meat. The report by DG for Health and Food Safety estimates that out of the 550,000 rabbits slaughtered in Malta in 2016, 90% or rather 500,000 were sourced from backyard farms, direct and local sales. This clearly indicates that the bulk of rabbit meat originates from these small holdings that while being invisible due to the lack of registration they potentially have a significant hidden contribution towards the national efforts to increase food security and minimise food waste. While these operations do not necessarily operate on a truly commercial basis, they embrace circularity. These rabbits are usually fed small amounts of pelleted feed supplemented with all the edible scrapes that the owner's kitchen can generate.

Other constraints that emerged in this study are the following:

(A) The fact that Malta is detached from mainland Europe renders the islands dependent on other countries for the procurement of feed-grade grain, feed supplements, cages and equipment, pharmaceutical products, and breeding stock. This dependency exposes the sector to the volatility of international markets, while connectivity to mainland Europe is weather-dependent.

(B) As a general rule, although a course is offered by one of the higher educational institutions, producers have a lack of basic knowledge on rabbit husbandry and practice, and less than adequate stockmanship. There are no extension services in place on rabbit husbandry and stockmanship.

(C) Climate, inadequate environmental control in barns, and the restricted farm footprint, leading to make-do and crammed farm designs come together and translate into a significant constraint both on day-to-day operations and also with regard to the potential further expansion of the activity.

(D) The current state is that there is a limited amount of health professionals that tend to commercial rabbit farms, animal nutritionists, agriculture engineers capable of designing adequate production barns, and laboratory diagnostic facilities. Since these con-

straints have an international as well as a local dimension, the recommendations for improvement of this sector can only address the ones that have a local context. The results indicate that the overriding constraints relate to the fact that the sector does not have an administrative structure, as well as the poor level of producer knowledge on aspects of husbandry and stockmanship. Thus, there is a desperate need to re-train and upgrade the educational level of the producers and organise the industry.

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