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The effects of summer heat in a Mediterranean climate on dairy cows;
A Maltese case study

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Abstract

The thesis aims to identify the physiological effects of the Mediterranean summer climate on dairy cattle in Malta. It is also a look at many factors in Malta's farming industry that contribute to easing the heat stress caused by the climate and an analysis of the sufficiency of these techniques. The study takes into consideration 20 dairy cows at random from different age groups and different phases of lactation from a farm of 300 Holstein- Friesian cows situated in the Northeast of the island of Malta. It will take place in the hot and humid summer month of September when the air temperature can reach up to 40 ºC and the humidity is at its highest. Various behaviour of the dairy cows will be recorded in association with their response to the heat as well as the air temperature and humidity every day for a period of 1 week. It was important to investigate the physiological effects contributing to the animal welfare aspects that heat stress has on dairy cattle which is becoming a concerning contemporary issue in Malta and Mediterranean climates.

Absztrakt

A szakdolgozat célja, hogy megvizsgálja, milyen élettani hatásai vannak a mediterrán nyári éghajlatnak a máltai tejelő szarvasmarhákra. Vizsgálja továbbá a máltai mezőgazdasági ágazat azon tényezőit, amelyek hozzájárulnak az éghajlat okozta hőstressz enyhítéséhez, és elemzi e technikák megfelelőségét. A tanulmány során véletlenszerűen – egy Málta szigetének északkeleti részén található 300 holstein-fríz egyedet számláló gazdaság különböző csoportjaiból, különböző életszakaszokból – került kiválasztásra 20 tejelő szarvasmarha. A felmérésre a forró és párás nyári szeptemberi hónapban került sor, amikor a levegő hőmérséklete elérheti a 40 ° C-ot, és a páratartalom a legmagasabb. Az állatok viselkedése 1 héten keresztül minden nap rögzítésre került a hőre, valamint a levegő hőmérsékletére és páratartalmára adott reakciójukkal összefüggésben. Fontos kiemelni, valamint csökkenteni azokat a hatásokat, amelyek állatjólléti szempontból hozzájárulnak a tejelő szarvasmarhákat érintő hőstressz kialakulásához, mivel ez a probléma Máltán és a mediterrán éghajlaton egyre aggasztóbb kérdéssé vált.

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1 Introduction

The farm chosen for this study is situated in the village of Naxxar, Malta, in the north eastern part of the island. It is a family-owned farm comprising of the owner George Vella, his brother, and his two sons Brian Vella and James Vella. They all work on the farm full time, milking and feeding a total of around 300 dairy and beef cows of the Holstein- Friesian breed. The beef cattle are only a by-product of the dairy industry, as there is not a large market for local beef in Malta and are mostly sold to private middlemen. However, the Milk Producers Cooperative helps farms raising beef cattle to find a market where they can slaughter them in good conditions and at good prices [1]. They are proud awardees of multiple trophies obtained on the basis on their superior quality of milk.

Additionally, a very important factor that leaves a great absence in the farming industry is the lack of farm animal vets. There is an abundance of small animal vets but very few will accept or are comfortable working with large animals. For this reason, upcoming vets have very little opportunity to learn from experienced farm animal vets, further decreasing the likelihood of newly- graduated farm animal vets. With a future of raising temperatures due to global warming, especially in Mediterranean countries like Malta, where temperatures and humidity keeps rising during the summer months year by year, the welfare of dairy cattle becomes a great concern that must be addressed [2].

I chose this theme in particular since being a Maltese citizen and vet student I have first hand experience witnessing the farmer’s struggle to upkeep the farm in summer months due to the increasing summer temperatures and increase of electricity and water bills. This also directly effects the welfare of the cattle and their ability to perform and produce good quality and quantity products which will in turn reduce economic return for the farmer’s and Maltese economy. Additionally, we have a lack of farm animal vets in Malta making it very difficult for farmer’s to access the necessary medications and treatments for their animals when needed.

2 Literature background

2.1 The climate of the Maltese Islands and agricultural ways

Cereals and feedstuff for animal feed are not grown locally, instead they have to be imported. The leading Maltese importer for this is known as The Milk Producers Cooperative (KPH). This important feedstuff is then manufactured by the local feed mill, also owned by KPH, for different livestock groups [1]. The Maltese Islands are found in the centre of the Mediterranean sea with an area of 316 km^2. The climate is Mediterranean type, characterised with an average monthly temperature range of 12-26 °C and sunny and windy days [3]. In summer the air temperatures have reached up to 40ºC with high humidity making it unbearable for humans, one can only imagine the effects left on the livestock. With this, Malta's small and restricted size limits the amount of land available for farming and its efficiency, growing crops or grazing. Data collected in the FSS 2010, describes a recording of 25,600 places for cattle where no stanchion tied stables were registered, loose housing with solid dung and liquid manure of cattle made up 97% of cattle housing and the rest were housed in loose housing with slurry [4]. In attempt to summarise the agricultural landscape on the Maltese islands, one can identify three distinct types of areas. The first area known as "Rdum and Gnien areas" which is used primarily for growing fruits or vines. The second is called "The Xaghra Area" which translates to a barren meadow as it is very difficult for plants to grow here due to the properties found here like small areas of soil surrounded by rock. Only tough and hardy fodder and legumes can be found here. Finally, the third area is "the dry- farming area" which consists of a large part of arable land where farmers can grow different crops depending on the geography of the place and the water supply [5]. The dairy cows are only allowed in their grouped stable on the farm. They are separated based on the number of lactations of the cow in question. The calves are held separately in small individual holdings away from the adults. The farm used for this research is equipped with water sprinklers over the cow stable, dry beds for the cows and large fans on the ceiling above the cows attached to a fortified tent that shades them from the sun (**Figure 1**).

Figure 1: The farm used for the research (left up: the stable for adults ; right up: separate place for calves; left down: feeding area for adults; right down: individual holding, feeding and drinking for calves)

The agricultural sector is not well financed, and it is currently not a priority to help the dairy cows combat the heat. There is a room for improvement in terms of welfare for the dairy cows particularly during the difficult summer months in Malta. Notwithstanding, this research aims to identify the effects of the summer heat on the dairy cows and looks to suggest more efficient ways to decrease the heat stress on the cows and increase the well-being of them, furthermore this can consequently increase the milk production.

2.2 The history of Maltese dairy farming

Until the 1930's, most milk provided to the Maltese citizens was produced by the indigenous Maltese goats but after cross-breeding the indigenous goats with the British- Saanen- types goats there was a complete loss of the original Maltese goats. The result of this cross breeding gave rise to hardy goats with very good milk supply. However, Malta saw a decrease in goat population in the later 1930's since it was increasingly harder to grow crops and feed the goats in the post-war period. The goat population never fully recovered after this due to the increase in forage costs, lack of land for grazing, new laws and regulations for goats' milk and the increased availability in cow's milk [6].

Later in the 1940's, increased amount of undulant fever, caused by Brucella melitensis, cases occurred due to the consumption of raw goat milk [6]. Undulant fever caused financial troubles for the public as the disease would leave the affected persons disabled which consequently left a toll on the amount of people needing medical help and those capable of working. Before pasteurisation of milk, people were advised to boil the milk before consuming and it was forbidden to sell raw milk. In 1938, the first centre for milk pasteurising was opened and pasteurised milk was available to the population [6].

As Malta was seriously affected by the repercussions of the war, imported animal feed came to a halt and in attempt to compromise the fresh milk shortage, Maltese people had access to a rationed amount powdered milk. After the war, the Maltese government began to buy both cow milk as well as goat milk to ensure pasteurisation before consumption. In attempt to increase the cow population and decrease the dependency on goats, the "Disease Eradication Scheme" in 1956 was created and offered the ability to surrender 12 diseased goats with 1 cow, and hence, the increase in cow population and milk shops over Malta and Gozo [6]. Eventually, more pasteurisation units were opened on the islands, the sale of raw milk was strictly prohibited and as of 1986 the government handed over all responsibilities of dairy farming to a private company that still stands today – Malta Dairy Products (MDP) – which came up with the brand "BENNA" for a range of dairy products [7]. Till this day "BENNA" is still Malta's local dairy product provider in partnership with 89 dairy farms over Malta and Gozo, comprising around 6000 local dairy cows. The company will pay the farmers based on the milk quality their farm produced, and will also be rewarded trophies for the best quality milk [7].

2.3 Modern day cattle farming in Malta

A major step forward in the Maltese dairy cattle farming industry and the agricultural industry was made due to the process of Europeanisation. Europeanisation for the Maltese dairy sector came with challenges due to the limited arable land combined with small areas of land due to land fragmentation [8]. Land fragmentation is a process whereby landowners divide their land amongst their descendants.

Moreover, the lack of rainfall and access to water discourages pastures for livestock and local production of feed and grain for the animal feed. Additionally, the Maltese soil lacks organic content which decreases the quality of the forage grown [8]. This means that there is major reliance on imported feed from other Member States, which ultimately imposes a financial burden for the Maltese farm owners due to the sea transport costs which are considerably higher compared to our counterparts that have a larger volume of purchases. It is for this reason of the need for feed importation that milk production in Malta has such high operating costs [8].

Considering the above disadvantages, Malta qualified for a "transitory package of state aid" through the special Market Programme of Maltese Agriculture (SMPMA) [8]. This programme provided a direct income to farmers between 2004-2010 in order to help with the imported competition. The KPH and its subsidiary company Malta Dairy Products (MDP), were and still are the primary stakeholders in the dairy sector- whereby they aim to improve the social and economical aspect of the dairy industry. Some responsibilities include, manufacturing feed, providing farm equipment, education and training to members and also technical support for improvement of nutrition, management, efficiency and quality [8].

Between 2003 and 2013, due to the financial burden caused by Europeanisation to meet the EU laws, it is unsurprising that the number of farms decreased from 184 to 120, as farmers could not afford to upgrade their farms to a standard acceptable by EU regulations [8]. Farms in Malta nowadays are small scale and run by a sole- holder or by family members on a part- time basis. In fact it is reported that 98.6% of the holding on the Maltese Islands are owned by a sole holder [9].

2.4 Dairy cattle farming vs beef cattle farming

Beef cattle farming's major issue is its effect on the environment in terms of the extreme amount of contribution to global greenhouse gas emission as well as its role in land degradation and deforestation due to the large amount of land required to have a beef cattle farm [10]. Often times, there is an interaction between beef production systems and dairy production systems, whereby the dairy cows produce both meat and milk and any extra calves are fattened for the meat production ,which is a practice commonly used in Malta [1, 10]. In case of more specialised beef production farms, only meat is produced from the cows and their calves which also leads to another difference whereby in such systems the mother and her calves are left together to suckle for a longer period of time compared to dairy cattle [11]. Additionally, beef cows are more commonly seen being raised on pastures or feedlots [11]. With this information and the lack of land in Malta it is not possible to maintain beef cattle on pasture.

Additionally, due to the "Nitrates Action Programme" whereby legislation imposes measures over all agricultural spaces in attempt to protect and minimise the nitrate levels in the soils as well as surface and ground waters from organic fertilisers such as manure produced by cattle and also inorganic nitrates [12].

2.5 Heat abatement systems used on Maltese farms

Common heat abatement systems that can be used to decrease the heat stress in dairy cattle include the increase of air velocity around the animals, reduction of ambient temperature using water evaporation in the air and using wet pads, cooling via evaporation by spraying water on the livestock, mechanical air cooling in specific areas and feeding at strategic times during the day like in the morning and evening to reduce heat production during the day when ambient temperature is the highest [13].

Apart from the high temperature experiences in Malta, particularly in summer, we also suffer from high humidity. In Malta, we make use of cover open sided structures and concrete and cement slabs are commonly used [13]. We have an intensive production of dairy cattle whereby the livestock spend their whole life cycle indoors due to limited space, governmental ownership of 66% of territory and since livestock producers are not land owners [13]. Despite these circumstances, our housing system is not up to standards especially in the hotter months. This is because the extent of livestock activity is not enough to justify investing so much money to improve these conditions [13]. It was found that to fix this animal housing issue, some of the aspects must be addressed:

- Architects are considered the only competent authority to be able to request construction permits of an animal barn, who do not properly understand the animal and farmer's needs. Sometimes, it is the farmer's that tell the architect what is needed which are ideas that are outdated and lack proper educational foundation [13].
- The use of globigerina limestone which is locally sourced from quarries is the most commonly and basic unit of building material all over Malta which comes with certain disadvantages. These include its erosion ability with time which can cause structural problems. However, it does keep cool in summer and warm in winter [13].

The heat abatement strategies implemented in the farm to be studied as well as many other farms in Malta include a number of different factors. The farm is comprised of an open sided structures and concrete surfaces for flooring made of globigerina limestone which is known to keep cold in summer [13]. The National Climate Change Adaptation Strategy in 2010 allowed the introduction of simple but better heat abatement strategies. These included the adjustment of shading strategies, investing in more farms that are naturally aerated or making use of ceiling fans as well as using sprinklers to cool the livestock [14].

Making use of shady areas or creating shade for the livestock is found to be advantageous for the livestock and indirectly for the dairy production as the cattle were found to have less respiratory rate and lower core body temperature when compared to those in unshaded areas [15]. Using sprinklers or misters allow the cattle to naturally dissipate the heat along with the use of fans are effective in heat removal from the livestocks' body by evaporation [15].

2.6 Heat regulation as described in Maslow's pyramid and the Five Freedoms

Maslow's pyramid is a concept created by the American psychologist, Abraham Maslow, in attempt to describe human motivation and how one can reach self- actualisation [16]. In his theory, he claims that each person has a series of needs that must be satisfied in order to reach one's highest self and these needs range from basic physiological needs at the bottom of the pyramid to self- actualisation at the top of the pyramid [16] (**Figure 2**). From an animal welfare point of view, the first phases of the pyramid can be known as the ‘care zone’ and those above the ‘care zone’ can make up the ‘Welfare Zone’ [17].

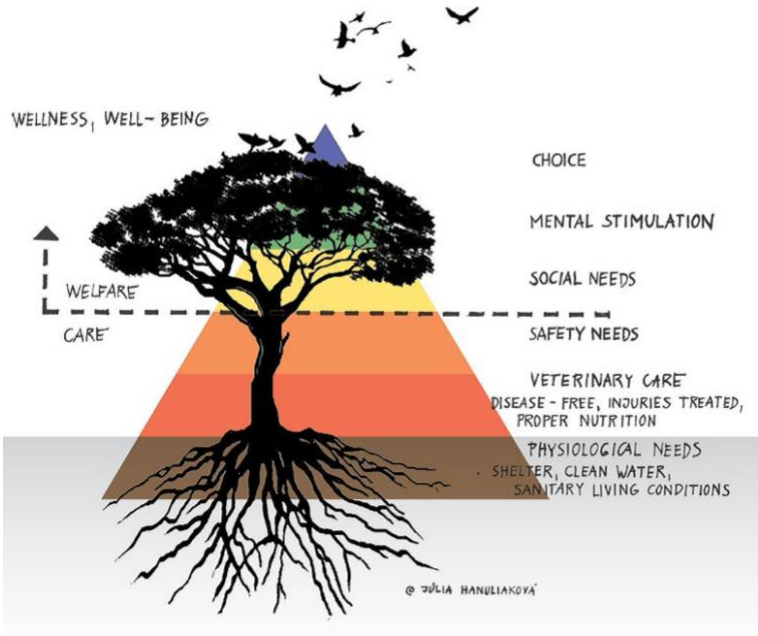

Figure 2. Diagram of Maslow's hierarchy of needs for animal welfare and care [16]

As you ascend the pyramid by firstly satisfying all survival needs, it becomes increasing difficult due to environmental obstacles as well as other interpersonal reasons [18]. In the lowest part of the pyramid are the physiological needs which can be shared by those required by animals for survival. These include biological requirements such as food, drink, rest, shelter, air, activity and also thermal regulation [18]. Therefore, one can argue that if not all physiological needs are met, which are the backbone of survival, the body cannot function as it should [19]. To extrapolate for the purpose of the theme of this study, dairy cattle undergoing heat stress prevents them from their basic, physiological need to heat regulation which in turn takes a negative impact on their body functions.

The five freedoms were introduced by Franklin Roosevelt where he spoke of the freedom of speech, worship, freedom from want and fear. [20] This was then adopted by the Brambell Committee in terms of farm animal welfare, in particular those in intensive systems which spoke of the right for these animals to be able to stand, lay, turn around, stretch their limbs and groom their body [20]. However, these were very restricted views, so a new and improved approach was introduced which include:

- Freedom from thirst, hunger and malnutrition
- Freedom from thermal and physical discomfort
- Freedom from pain and disease
- Fear from fear and distress
- Freedom to express normal behaviour [20].

As the second freedom states, the animal has a right to freedom from thermal and physical discomfort which is imperative to note as heat stress is a raising concern amongst dairy farms due to the increasing global temperatures [21]. Heat stress and thus thermal and physical discomfort has been shown to have negative effects on the wellbeing of the cow in terms of its reproductive ability as well as lowered milk production [21]. Studies show that when an animal does not have control over their environment, for example, seeking shade when feeling too hot to reduce their body temperature, there are risks to that animal's welfare [21].

2.7 Common heat related problems in dairy cattle in Malta

Heat stress, is a term used to describe high environmental temperatures that cause a disruption of the animals' heat production and heat loss capabilities. This, in turn, has been found to cause infections, production loss and mortality so the decrease of the well-being [2]. In the official Guidelines for the Animal Health Control Programme published by the Government of Malta states that the most common pathologies of bovine farm animals in Malta include calf diarrhoea, calf pneumonia, retained placenta and endometritis, mastitis and lameness [22]. Most of these diseases have a strong correlation to elevated summer temperatures and heat stress.

In case of calf diarrhoea, a study investigating gut health in neonatal dairy calves showed that the there is a great influence of maternal health, including heat stress, on foetal development and the offspring's health after birth, whereby there was found to be reduced transfer of passive immunity due to the less surface area in the intestines which can contribute to calf diarrhoea [23]. Another study by Ahmadi and Mirzaei found that the incidence of retained placenta increased along with an increase in temperature and heat stress [24]. Very commonly, mastitis is seen on dairy farms. The cause of this can be of many but one includes climate of high temperature and humidity [2]. This was studied as an increase in the temperature- humidity index (THI), which is used to define heat stress in cattle, showed increase in somatic cell count (SCC) and more instances of clinical mastitis [2]. In hot and humid condition, the cattle can be seen with muddy udders due to laying in wet, cooler areas which ultimately predisposes them to intramammary infections [25].

Lameness, another common problem in Malta, was seen to be characterised by cows preferring to stand on cushioned surfaces of the stall and less in the alley which can also contribute to the cow not being able to stand under the sprinklers and effectively cool off, making them more prone to heat stress [22, 26]. Lame cows in high THI were found to spend longer times standing due to difficulties raising and laying down, and there were found to be more lame cows at the end of summer compared to those at the beginning of summer [26]. Additionally, cows can be seen panting in order to cool themselves down during hot temperatures, this causes a shift in their acid- base homeostasis [27]. As the respiratory rate increases it causes a respiratory alkalosis due to the removal of CO_2 via the respiratory route. [27]. A decrease in dry matter intake (DMI) during heat stress can be seen increasing the incidence of ruminal acidosis [26]. Factors affecting the subacute ruminal acidosis (SARA) can be due to the lack of eating and chewing cud, increased respiration and excessive saliva loss thus reducing the ruminal buffering system [25].

Heat stress effects on reproduction have also been studied linking high environmental heat to longer conception times [25]. The heat stress on the mother can lead to loss of embryo at the early stages, failure to establish and maintain the pregnancy after fertilisation [25]. Also, the lack of DMI causes negative effects on energy balance that can lead to lower calf birth weights [25].

2.8 The physiological impacts of heat on dairy cattle

Studies have shown that when the upper critical temperature limit within the thermoneutral zone is surpassed due to the ambient temperature, the dairy cattle undergoes physiological heat stress [29]. To deal with this change, dairy cattle have had to adapt their behaviour to reduce their heat production and increase their ability to lose heat in both a behavioural and physiological way [29].The following are a list of behavioural changes experienced by cattle under heat stress as found in a study: [30]

- decreased feed intake, dry matter intake (DMI)
- feeding time was either increased or decreased dependant on the milk yield of the cow
- increased time spent drinking
- decreased lying time but increased lying bouts
- increased standing time
- decreased locomotion
- increased aggressive interactions and vocalisations
- increased shade seeking and seeking well- ventilated areas [30].

Certain behaviours adopted as a rection to heat stress serve as telltale signs of the welfare of the animals as it has an impact on not only behaviour and physiology but also the reproductive capacity of the cattle and the productivity [30]. Some of these behaviour changes include restlessness in the form of their time spent laying down, standing and resting, the amount and volume of their food and drink, fearfulness and motor activity [30]. The thermo-neutral zones of many cow breeds range within air temperatures of -0.5 to 20.0°C and a relative humidity of 60-80% [30]. When these thermos-neutral vales are exceeded together with other environmental factors such as wind or air movement and shade and sunlight intensity, heat stress is experienced by the cattle causing physiological and behavioural changes to counteract it [30]. Individual differences between cattle can also affect their ability to lose heat such as body surface area, subcutaneous fat, thickness, density and length of their coat as these are all essential variables contributing to the rate of evaporation [30].

Homeostatic mechanisms are also activated when thermoneutral zones are exceeded within the cattle's body in order to maintain physiological balance, including adjustment in metabolism of energy as metabolism increases heat production [30]. Hence, the overt behavioural change due to this internal change will be a reduced feed intake or lack of appetite, resulting in energy being derived from glucose and myofibrillar proteins which produces less heat when compared to their counterpart, fatty acids [30]. Thus, behavioural changes, such as reduced feed intake, aim to support the heat stress induced physiological changes to ultimately maintain homeostasis and these physiological changes are triggered by heightened respiratory rates and heart rates, milk production and reproduction [30]. Water intake and the time spent drinking water is seen to be increased during times of heat stress as the cattle seeks to replenish the water lost through urination, defecation, cutaneous and respiratory evaporation and in seriously heat stressed cows, panting, sweating and excess salivation was noted too [30].

Other behavioural changes adopted to counteract the heat stress experienced include motor activity changes such as socialisation tactics and preferred areas to rest in the barn or pasture if available. The cattle's' daily pattern also differs in response to heat stress and lying times are also decreased [31]. Lying times and socialisation are extremely important for the cattle as they spend between 12-14 hours a day laying down, 3-5 hours a day eating and 2-3 hours a day socialising, but these patterns can be disrupted based on the environmental conditions. For example a study by Cook et al. proved that lying time was most affected with an increase in THI as it was recorded to be reduced by 3 hours [30]. In fact, during heat stress the cows experience lethargy and are found lying more often in the manure filled alleyways as they seek the wetter and colder concrete floor compared the hotter soft bedded cubicles in attempt to cool down [30]. The lying position is a very helpful animal welfare indicator as it plays a part in the control of hoof disease, lameness and increases feed intake and rumination [30]. In summary, the cattle spend longer periods standing and less time lying at shorter lying bouts when suffering from heat stress [30]. Longer standing times prevents adequate blood circulation to the udder but this position is preferred when the cow is feeling hot due to the increased body surface area for heat to be lost via convection [30].

Vocalisation is often considered and examined in behavioural studies as it provides useful insight in the physiology and welfare of the cattle [30]. The frequency of sounds made depends on the physical state of the cow, be it lying, resting, in pain or stressed and individual sounds can also be provoked during painful or therapeutic procedures [30]. Increased vocalisation is noted during weaning of dairy calves to indicate their hunger too [21]. Polsky and von Keyserlingk hypothesized that heat stress can stimulate a distressing vocalisation as a response as they experience a certain degree of hunger and low satiety [21].

2.9 *How is heat stress on dairy cattle becoming a greater concern?*

Studies show that there is an estimated 7% of total cattle population globally that suffer from heat stress which is a number that is set to increase drastically before the year 2100 to approximately 48% when taking into considerations the exponential growth of emissions [32].

This not only poses a great threat and concern for the welfare of these cattle but also those effected by their decreased production due to it [32]. Not only does the increase in global temperatures affect the animal directly through heat stress but one must also think of the indirect pressures caused on agricultural and livestock production such as effects on the feed resources as grasslands must adapt to the various changes in patterns of precipitation [32].

Apart from the impending doom posed upon livestock by global warming, there is also the increase demand of production due to the exponential growth of the human population meaning a need for livestock intensification [32]. However, this sentence alone gives rise to the negative cycle that shows how increase in livestock gives rise to increase of greenhouse gas production, approximately 14-18% of the total amount, this increase in greenhouse gases contributes to global warming which is a major factor is causing heat stress in the livestock [33]. Apart from the correlation with intensification and its contributions to climate change, there is also a link to worsening animal welfare one of the reasons being that there is a decreased human: animal ratio so there is less attention to each individual animal [34]. Additionally, an increase in number of cows in the barn will mean an increase of cows at the feeding trough which will cause aggression levels to rise and higher stress levels amongst the cows because of the social intimidation caused [34].

A solution to this intensification and climate change relationship problem is to aim towards higher productivity per animal [33], although easier said than done, this is a good motivator to encourage more research, heat abatement strategies and better technologies to combat heat stress for the wellbeing of the animals, which will in turn have higher productivity and ultimately reduce the negative effects on climate change.

2.10 What tools, techniques and technologies exist that can be used to remedy heat stress on cattle?

With an increased ambient temperature, the cows' primary non-evaporative cooling methods via processes such as radiation, conduction and convection are less effective so the cow must resort to evaporative cooling methods such as sweating and panting [35]. Unfortunately, with higher relative humidity these evaporative cooling measures are not sufficient which causes a rise in the cow's body temperature [35].

By appealing to the animal's non-evaporative methods of cooling, strategies and heat abatement technologies can be used to aid these methods to be more efficient. The first line of defence against heat stress can be as easy and as economical as providing proper and abundant shaded places as this can reduce the total amount of heat load from 30-50% [35]. This was also proven in studies that in shaded areas, cows had lower rectal temperatures, lower respiratory rates and an increase of milk yield by 10%[35]. Shaded places can be obtained by a number of various ways such as use of trees or roofing that has reflective coating [35].

Since shading will only help in terms of reducing the solar accumulation and not in the reduction of the relative humidity or air temperature, other cooling options include use of fans and sprinklers or a combination of both [35]. Another way of cooling the cows commonly used in in climates where humidity levels are lower is the use of misters to make the evaporation rates more efficient [35]. Israeli farmers have used a system of forced ventilation and wetting of cows ever since this method was described 25 years ago periodically throughout the day, 5 times per day in 30 minute instances per time [36]. Similar methods were used on the farm used for this study with the use of sprinklers, shaded barns hanging fans and ceiling fans as seen on **Figure 3**.

Figure 3. Left above; ceiling fans, Right above; sprinklers, Left below; shaded barn, Right below; hanging fans

Cooling of lactating cows and that of dry cows should be given equal importance. Although lactating cows produce larger amounts of heat, classifying them at higher risk of heat stress than dry cows, the latter should also be protected from the heat [35]. High temperatures have had negative effects on dry cows 60 days prepartum in regards to the cows fat and milk yield during periods of early and mid-lactation [35]. In fact when comparing shaded and non- shaded dry cows, it was seen that those shaded gave birth to heavier cows and produced a higher milk yield, they also had lower vital measurements and different hormonal patterns [35]. Dry cows that were kept cool using fans and sprinklers provided even larger calves and higher milk yields when compared to those in shaded areas only [35].

Giving the cows the option to graze could also improve their behaviour and response to heat stress. Grazing has been found to provide various benefits for cattle welfare as it promotes lying and resting periods as well as been seen to decrease episodes of aggressive behaviour amongst the cattle [30]. A constant supply of fresh and cool water is also extremely important particular during hot months due to the increased evaporative cooling [30].

The structure of the farm should also be designed to support all types of climatic conditions, incorporating open sides, large windows and open areas to allow the natural breeze to cool the animal in a passive, natural way [35]. In cases when wind and natural breezes are not present, for example in peak summer months, the use of mechanical ventilation such as fans [35]. Another change that can be made to help the cows during this period of heat stress is adjusting their nutritional formulation since during this time they have a reduced DMI [35]. It is recommended that during hot weather, the rumen degradable protein should not surpass 61% of the dietary crude protein, however this issue is still yet to be studied in more detail [35]. Since energy intake is the major problem during summer months farmers can bypass this problem by decreasing the amount of forage as it will encourage feed intake and increasing the amount of concentrates in the feed, in this way they are increasing the energy density [35].

A key improvement that will improve dairy cattle welfare by helping to remedy the effects of heat stress by treatment or early diagnostics of the signs of heat stress is the increased presence of veterinary services on farm and better farmer education [37].

Notwithstanding, there has also been research on mitochondrial DNA analysis of *B. indicus* and *B. taurus* that indicates divergence from the former to the latter due to adaptation to living in hotter, more arid climate with lack of rainfall [21]. This insinuates that *B. indicus* breeds would be evolutionary more adapted to thrive in hot conditions and would be able to perform and handle heat stress in a more efficient manner that would also ensure better welfare for the animals [21]. Whereas, *B. taurus* breeds, such as the Holstein or Holstein Freisian would be better suited for temperate conditions as they may not withstand the effects of heat stress and other negatives that come with hot climates, thus reducing their welfare and efficiency to produce their maximum yield [21].

2.11 *Why should this issue receive more serious uptake?*

Studies have focused on the projected time in the future when there will be a biological threshold for global warming and its effects on the welfare and production of the cattle but they do not take into consideration the process of adaptation of these cattle along the way [32]. By analysing and experimenting different preventative or adaptive measures on dairy cattle already experiencing heat stress could be a huge step forward to safeguarding the animals' wellbeing, welfare and ultimately production, and ideally this could better prepare the livestock, the farmer and the consumer altogether [32]. Researchers could also identify regions that are more at risk of severe climatic change to more accurately calculate, prepare and prevent any livestock catastrophes and create better means of livestock viability [32].

Due to Malta's unique agriculture and agricultural systems dairy farms may suffer various complications such as lack of land and the large financial burden purchasing land comes with due to this and lack of availability of fresh water [13]. These constraints have pushed and encouraged a highly intensive husbandry methods which can negatively affect the welfare of the animals [13]. Despite efforts to give opportunities to buy locally sourced and produced products, Maltese citizens still tend to prefer buying exported good from supermarkets [13].

With summer temperatures becoming even hotter and drier every year, officials must be aware of the problems of heat stress and begin strategies to encourage researcher to create more appropriate techniques to tackle these issues as climatic conditions begin to worsen [13]. Not only must it encourage the research but also provide financial aid for these studies to take place as well as financial support for farmers to pay the ever increasing water and electricity bills used for the functioning of sprinklers and fans [13, 38].

3 Aims and objectives

The main objective of this study is to investigate the physiological effects contributing to the animal welfare aspects that heat stress has on dairy cattle which is becoming a concerning contemporary issue in Malta and Mediterranean climates. The study takes place in the month of September when humidity and ambient temperature are high which are commonly linked to heat stress [28]. Making use of the temperature- humidity index (THI) can point towards the comfort and welfare of the dairy cattle experiences during heat stress [28]. Besides the signs of reduced animal comfort due to heat stress, one can also notice the drastic milk production reduction during these hot and humid months, especially in Mediterranean climates which further highlights the need to take action to better the conditions for these animals [28].

4 Materials and methods

During this study a group of 20 randomly chosen cattle in different lactation stages were selected to observe their behaviour during a 1-week period during the month of September in Malta. The study aims to determine the behavioural response to the weather conditions of the dairy cows during this week and determine the animal welfare based on this behaviour. Monitoring of these cows occurred between 9AM and 11AM, during milking sessions and feeding sessions. The behaviour that was monitored during this time included the following:

- Presence or absence of panting
- Laying or standing positions
- Presence or lack of appetite
- Milk production
- Condition of the hygiene of the udder
- Presence or absence of lameness
- Rectal temperature
- Rate of respiration

Materials used to conduct this study included a thermometer to measure the rectal temperatures in degrees Celcius, observing flank movements and a stopwatch to count the respiration rate and milk measuring tanks to record the milk production in litres as seen in **Figure 4**. Presence or lack of appetite was recorded based on the reluctance of the cow to eat when being presented food. The udder was considered dirty if large areas of the udder were covered in dirt or if there were more than 3 smaller areas of dirt on the udder as seen in **Figure 4**. The lameness of the cow was established by watching her gait as she walked in the alleyway. The daily ambient temperature, wind speed and relative humidity was recorded using the Malta Airport weather forecast [39]. After the data on the farm was collected it was inputted into Microsoft Excel. The heat stress experienced by the cattle on the day was calculated using an online THI calculator by the company ‘Galebreaker Ltd’ and ‘Philbro Animal Health Corporation’ [40].

Figure 4 Left above: Measuring the milk volume; Right above: Lying behaviour; Left below: Udder hygiene ; Right below: Panting behaviour

5 Results

For everyday researched, the ambient temperature and relative humidity was recorded using the Malta International Airport weather updates [39]. The THI was then calculated using an online THI calculator and recorded as seen in the table below [40].

Date	**30/08/2024**	**02/09/2024**	**03/09/2024**	**04/09/2024**	**05/09/2024**
Ambient temperature (°C)	35	34	30	27	29
Humidity (%)	58	83	80	80	78
THI	86	90	83	78	81
'Galebreaker' level of heat stress:	Severe	Severe	Severe	Severe	Severe

As calculated above, on all days of observation the THI calculator eatablished severe levels of heat stress. They follow the table below as treshold numbers [40].

THI number	**Stress experienced**	**Effect on livestock**
<52	No heat stress	Comfortable, maximum milk production. No negative effect
52+	Very mild	Decrease rumination activity
57+	Mild	Oestruc activity decreases in long run
65+	Mild- Moderate	More visits to water trough and longer drinking time. More negative changes in cow behaviour. In the long run there is decrease in conception rate, more inseminations per pregnancy
67+	Moderate	Lying behaviour changes, more voluntary standing and increase lameness cases
68+	Moderate to Severe	Increase respiration rate (40-60 breaths per minute) In the long run the milk total volume and protein levels decreases
70+	Severe	Cow rectal temperatures increase. In the long run milk urea nitrogen uncreases

Throughout the study, the cows that were seen to be lame on the first day were lame throughout. In **Figure 5** is a pie chart depicting the ratio of lame to non- lame cows.

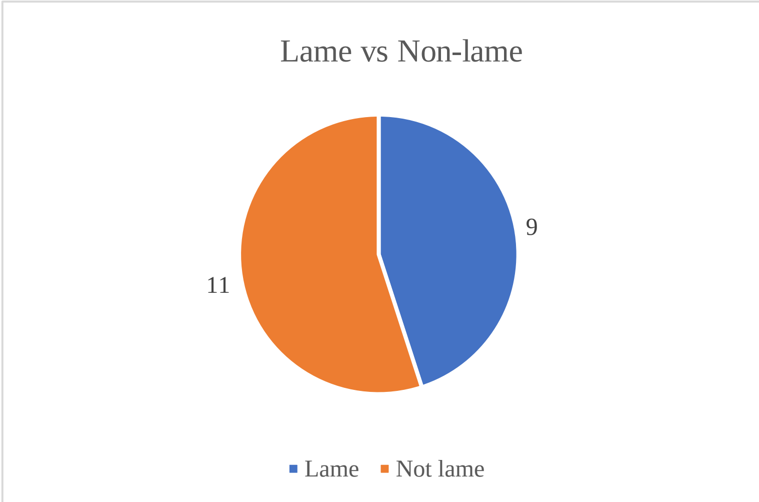

Figure 5 A pie chart of showing the lame vs non lame cows

Below, **Figure 6** is a graph showing the average respiration rates per minute and the average rectal temperature amongst the 20 cows on a daily basis compared to the THI of that day.

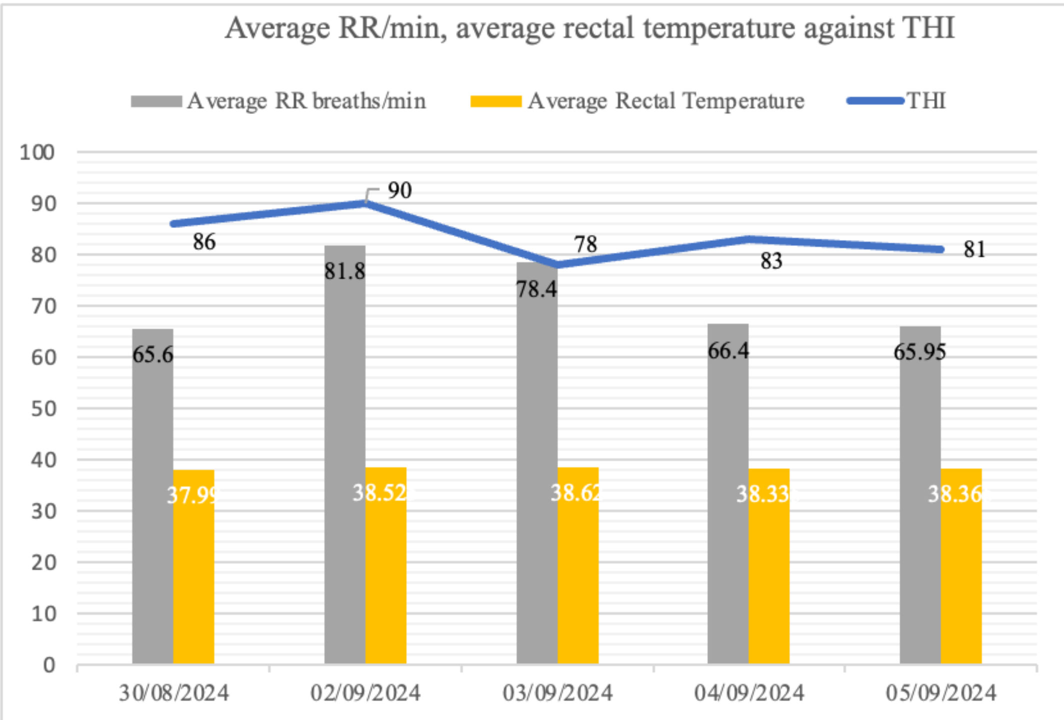

Figure 6 Graph showing the daily average respiration rates, average rectal temperatures and daily THI

The graph in **Figure 7** shows the daily average milk yield in liters from theh 20 studied cows compared to the daily THI scoring.

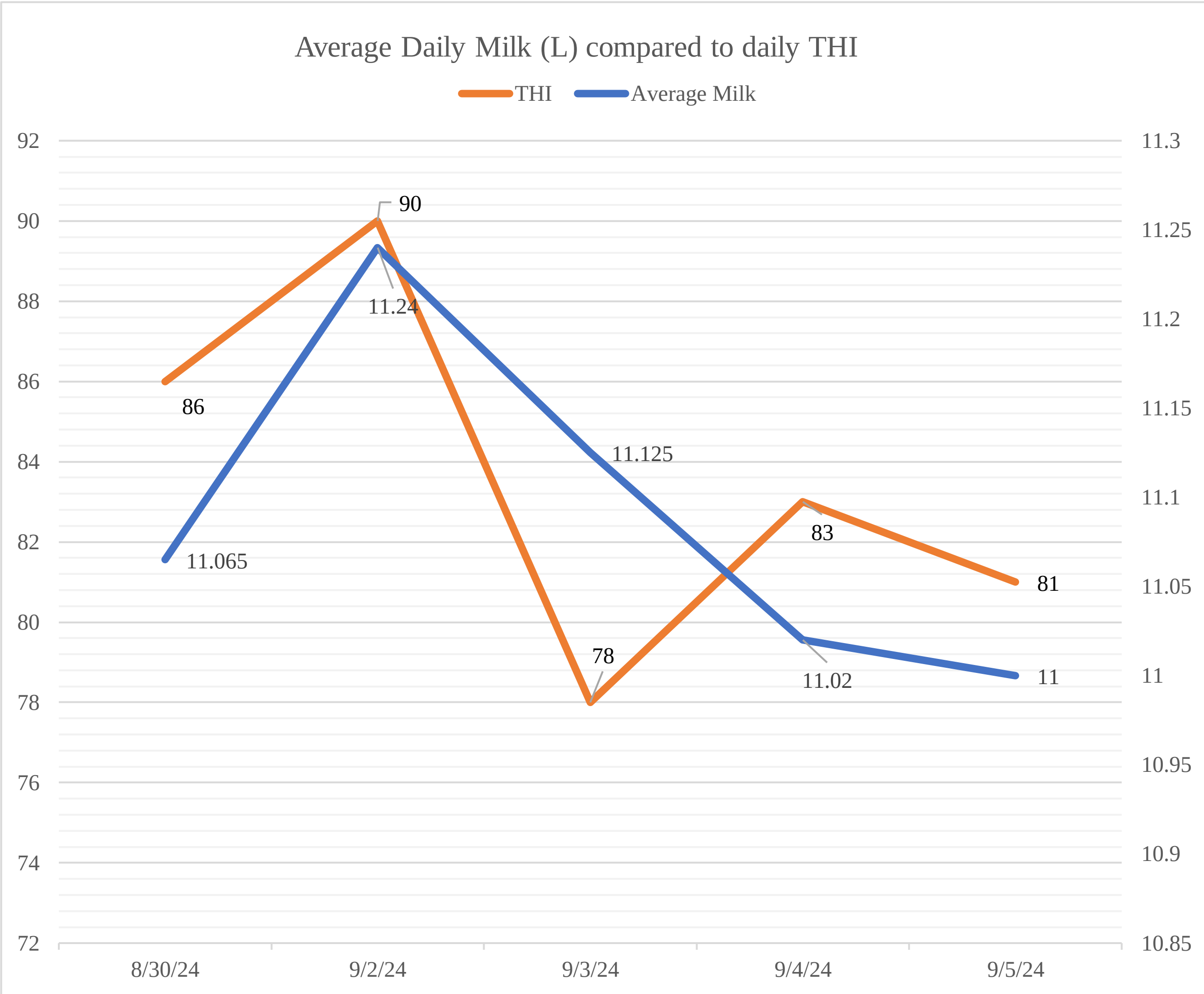

Figure 7 Graph showing the average daily milk yield (L) against the daily THI

In **Figure 8** there shows a compilation of pie charts for each day describing the number of cows found with a dirty udder and the number of cows found with a clean udder.

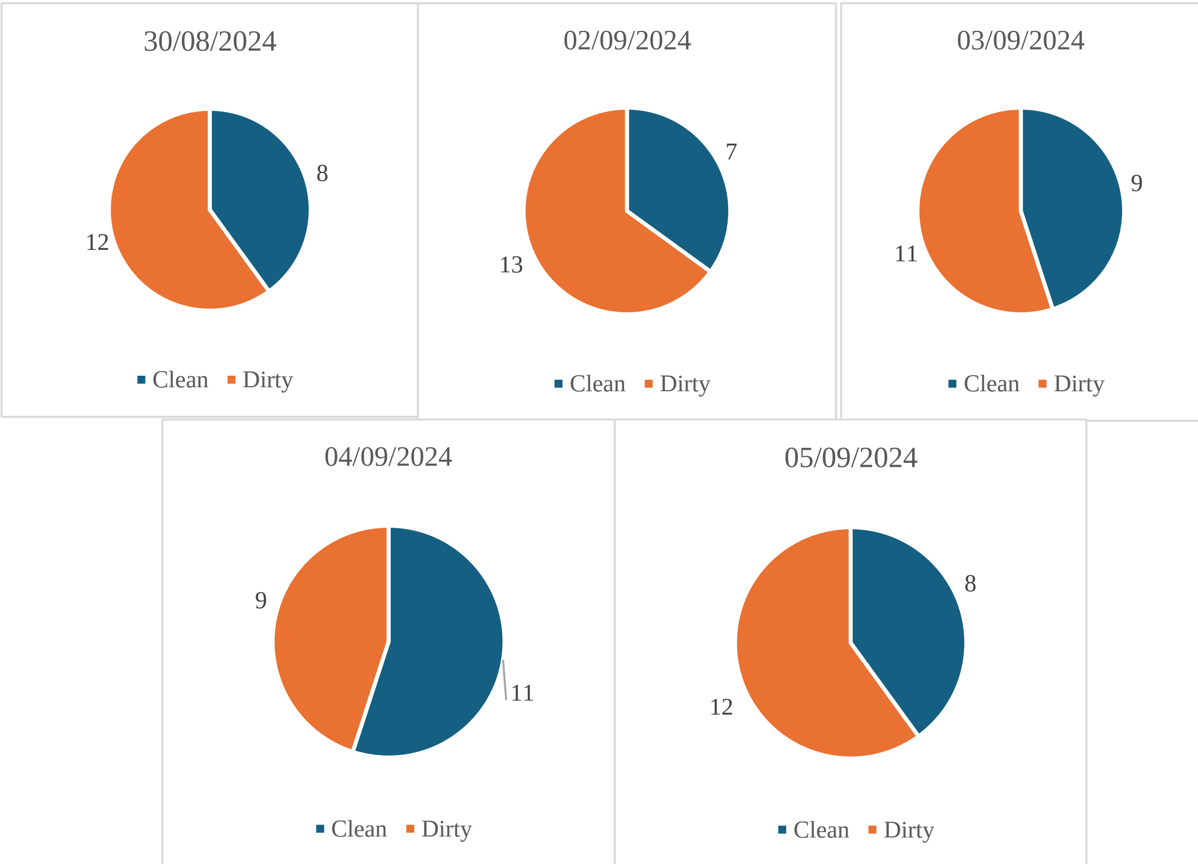

Figure 8 Daily pie charts showing the amount of cows with clean udders and the amount of cows with dirty udders

Figure 9 depicts the amount of cows with appetite and those without appetite and their corresponding average milk yield per day, as well as the daily THI for reference.

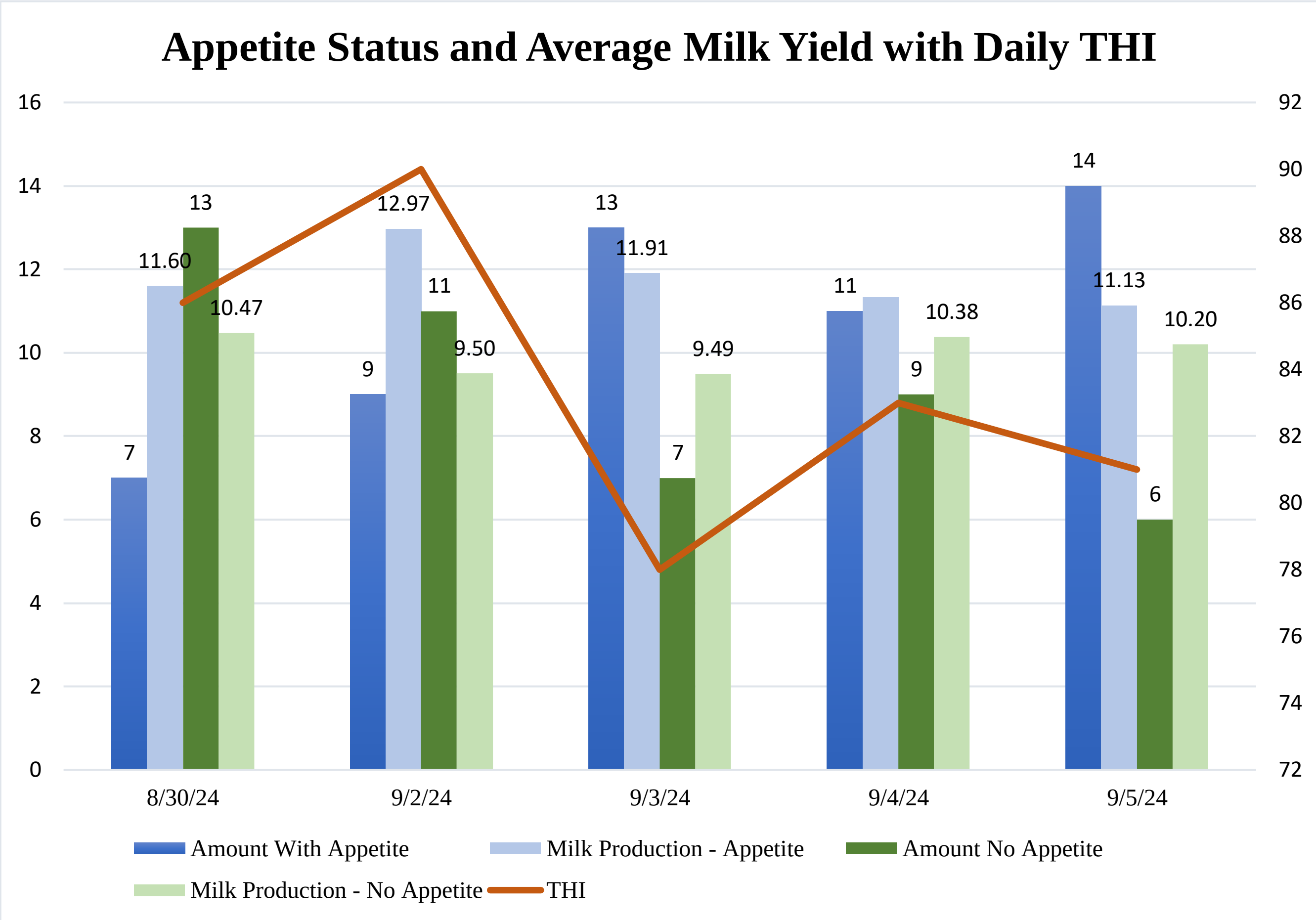

Figure 9 Daily appetite status with corresponding milk yield (L) and daily THI

In **Figure 10** below describes the cows' lying or standing position with the daily THI.

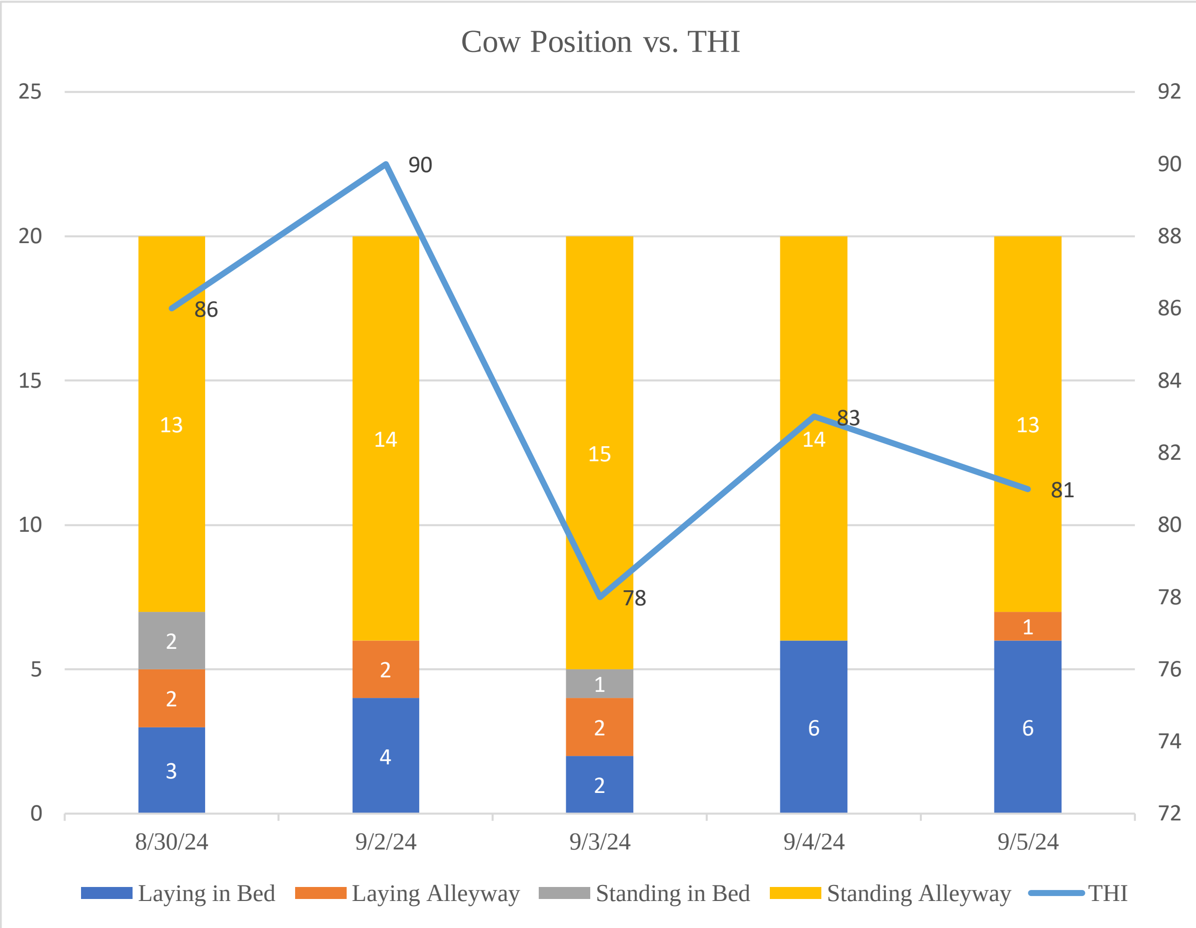

Figure 10 Cow lying positions and daily THI

In **Figure 11** below, the collection of pie charts show the amount of cows that were panting compared to those that were not panting on each given day.

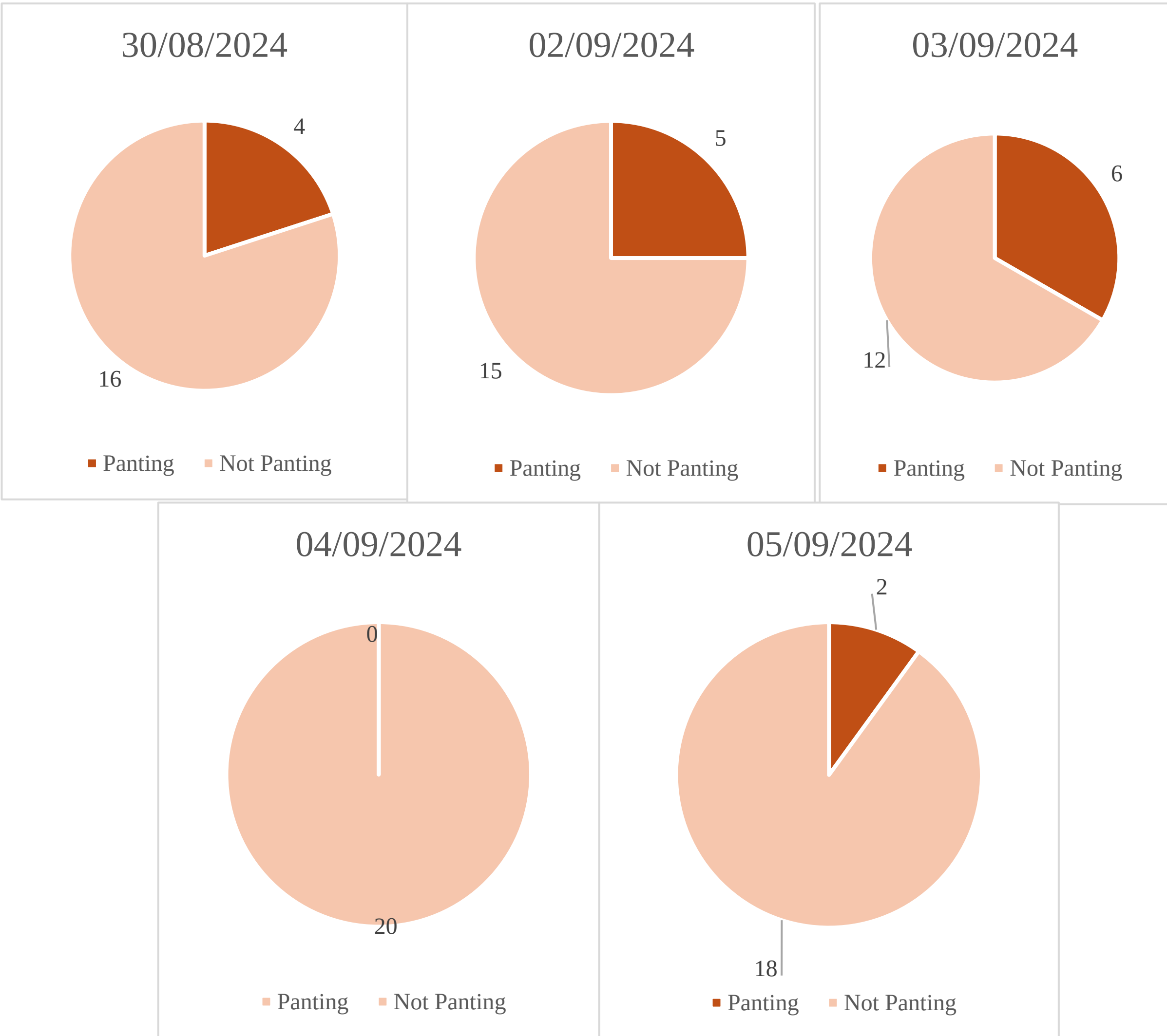

Figure 11 Pie charts showing amount of cows panting and not panting on each day

6 Discussion

As can be seen in the results, quite a high percentage of lame cows were recorded in the study as seen in **Figure 5**. Perhaps, better farriery, more attention to the cows' hooves and their gait and more frequent use of formaldehyde baths for the cows to walk through would be a beneficial way to combat this issue as it will not only increase the productivity of the cow but will alleviate pain and move towards a better welfare status for the cows.

In **Figure 6**, one can analyse the average respiration rate per minute being highest at an average of 81.8 breaths per minute on the day with the highest THI of 90. This shows that the cattle were uncomfortable on this day as they tried to remove excess heat via heightening respiration in the form of evaporative cooling. It was also interesting to note that on the 2nd and 3rd of September, when respiration rates where highest compared to the other days at an average of 81.8 breaths/ min and 78 breaths/ min respectively, there was also a high incidence of the amount of cows found panting. 5 cows were panting on the 2nd September and 6 cows on the 3rd September as depicted in **Figure 11**. Rectal temperatures were seen to be similar in values amongst the days as seen in **Figure 6**.

Milk yield average per cow per milking session was calculated to be between 11L and 11.24L, seen in **Figure 7,** which is not a very good yield as the farmer explained. He stated that in winter most cows can produce up to 25L. This shows how the summer months and the heat stress that is experienced during these months are very straining on the cow and the farmer alike. The cow is struggling to cope with the high temperatures and her milk production also reduces, which is a financial struggle for the farmer too.

As seen in **Figure 8** and **10**, the incidence of dirty udders is higher on the 2nd September with highest THI of 90 which corresponds to the highest incidenc of cows laying in the alleyway respectively. Laying in alleyway may be a behaviour adapted by the cows as the alleyway is close to the sprinklers which make the floor wet. The cow lays down in attempt to cool down by having more surface area touching the water which is cooler. Along with the wet ground, there is also a lot of faeces from the other cows making it a dirty environment and a breeding ground for bacteria and diseases. When the cow lays down, her udder is easily contaminated with the faeces and can increase the risks of mastitis. A remedy for this is a more frequent cleaning of the alleyways to try and minimise the faecal and bacterial load and allow a marginally cleaner alleyway for the cows to lay down. Additionally, better and more efficient heat abatement strategies such as more fans and a renovated sprinkler line would also be beneficial to minimise the heat load and hopefully avoid cows needing to lay down in the alleyway to lose the excess heat.

In **Figure 9**, we can see that the cows with no appetite had a lower average milk yield compared to their counterparts who had appetite. On the days with higher THI, there was more chance that the cows did not have appetite, showing the effects of heat stress on the cows.

Finally, in **Figure 10**, majority of cows were stnading in the alleyway on all days, some were seen eating, others were standing near the water troughs, some were under the sprinklers and others were standing in the dry beds. Few cows were seen laying down were either on the dry beds or had their back legs in the alleyway and their rest of the body on the bed and some cows were found laying in the alleyway to cool off. The lack of cows found laying in their beds resting could point towards their struggle to fight off the hot temperatures further indicating the harmful effects of heat stress on the welfare of the cows.

To conclude, strategies to help prepare Maltese dairy farms for the heat stressed months could include upgrading the existing heat abatement systems such as the fans and sprinklers to ensure better functioning, efficiency and perhaps also energy saving. Financial help for the farmers to cover electricity and water bills can also be beneficial during these hard times when milk production is low and thus the economy is slow. Introduction of genetic lines such as *B. indicus* breeds that are able to withstand hot temperatures can also be the way forwards in such a climate. Hoof maintenance and regular foot baths can reduce lameness incidence and also better the cow welfare and peformance.

Lastly, better farmer education about heat stress and its effects on cows to be able to better navigate these months and monitor stressed cows more vigilantly to prevent worsening of the health and welfare of the cow. More vet availability for farm animals is also a very big problem on the Maltese islands, thus introducing training programmes and incentives for graduated vets to be able to learn through hands on practice could be a huge breakthrough in farm animal veterinary medicine in Malta.

7 Summary

To conclude this study aimed to shed light on the struggles experienced during the hot months of summer particularly in a Mediterranean climate. By describing the Maltese climate as well as through the various observations found on the farm and research done regarding dairy cattle's behaviour during heat stressed months and the negative impacts of heat stress, one can see the animal welfare status deteriorates substantially during the summer and hot months. Not only do the animals suffer but the farmers also suffer financially due to the poor milk yield, lower birth rates, higher mortalities and higher incidences of disease. With this, one can insist that with the temperatures rising every year, it is a growing concern that people should be more aware of and farmers as well as vets should be well educated and should have up to date knowledge regarding heat stress and its problems.

Without any additional help, Maltese dairy farmers will not be able to pay for the large amount of costs that comes with heat stressed animals, and can also pose a threat to the local milk produce. It is definitely an issue that needs to be addressed for the benefit of the cows that must withstand the unbareable heat causing a disruption in their interal bodily functions as described in the study but also for the farmers and Maltese economy.

Stress must be put on introducing more innovative and better heat abatement measures, better disease prevention measures as well as encouraging and creating more incentives for vets to work with farm animals. In this way, I believe animal welfare statuses can increase drastically around the Maltese Islands.

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