Climate-Smart Livestock Breeding: A Study of Holstein-Friesian Cattle in Canada and Pakistan.

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Abstract

Climate change poses significant challenges to livestock production worldwide, necessitating the adoption of climate-smart breeding practices to enhance the resilience of livestock populations. This study investigates climate-smart breeding practices in Holstein-Friesian cattle, a widely used breed in dairy production, in both Canada and Pakistan. This research aims to assess the current status of climate-smart breeding initiatives and their effectiveness in improving the resilience of Holstein-Friesian cattle to climate variability in these two contrasting environments. Methodologically, a Qualitative approach is employed, combining quantitative analysis of breeding data with qualitative analysis of articles, books, and lab data. The finding of the study showed that Canada places a strong emphasis on genomic technologies and advanced cross-breeding, producing robust Holsteins with great milk production. The findings of the study showed that the surrounding atmosphere has an immense impact on the productivity of the Holstein Friesian. Pakistan's inadequate infrastructure and resources make it difficult to carry out such efforts. Despite this, indigenous knowledge and customary breeding techniques have the potential to increase climate resistance. Although it depends on animal breeding, Pakistan's agriculture industry faces low productivity because of managerial problems. Cooperation between the two countries could improve knowledge sharing and increase Holstein cattle's ability to withstand climatic change. The study contributes to understanding the climate-smart breeding practice and highlights the significance of collaboration to enhance livestock production.

Keywords: Climate-smart Breeding, Holstein-Friesian, Pakistan, Canada.

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Introduction

Livestock breeding plays a crucial role in global food security and agricultural sustainability. Livestock, including cattle, sheep, goats, and poultry, are valuable sources of protein, essential nutrients, and income for millions of people worldwide (Thornton, 2010). In addition to providing meat, milk, eggs, and other animal products for human consumption, livestock also contributes to crop production through their role in nutrient cycling, soil fertility enhancement, and draft power for ploughing and transportation (Herrero et al., 2013).

The most important role of livestock is the production of high-quality animal protein for human consumption through the supply of milk and meat. Milk production is the most efficient process of converting plant material into perfect food. Milk constitutes an integral part of our daily diet necessary for the nourishment and health development of the human being (Irshad et al., 2011). Previous Research has demonstrated how crucial it is to use climate-smart breeding techniques in order to increase the flexibility and resilience of Holstein-Friesian cattle to shifting environmental conditions. In response to rising temperatures and shifting weather patterns, research performed in Canada has highlighted the significance that genetic selection and breeding approaches play in enhancing the heat tolerance, illness resistance, and productivity of Holstein-Friesian cattle (Ghiasi et al., 2018). Additionally, research has looked into how genomic technologies, such as genomic and marker-assisted selection, might be used to hasten genetic advancement and lessen the negative consequences of climate change on cow breeding programs (Cai et al., 2019). Despite these advancements and studies, there are still significant gaps in our knowledge of climate-smart animal breeding concerning Holstein-Friesian cattle in Pakistan and Canada.

Climate change poses significant challenges to livestock production systems, threatening the health, productivity, and welfare of livestock worldwide (Thornton et al., 2009). Rising temperatures, changing precipitation patterns, increased frequency of extreme weather events, and shifts in disease patterns all have profound impacts on animal health, feed availability, water resources, and pasture productivity (Seo et al., 2015). These climate-related challenges are exacerbated by other factors such as land degradation, water scarcity, and socio-economic constraints, leading to decreased livestock productivity and increased vulnerability of livestock farmers to climate risks (Thornton et al., 2011).

The United Nations has launched a global initiative to promote climate-smart breeding programs for livestock species in vulnerable regions (UN, 2020). The United Nations focuses on developing climate-resilient livestock breeds adapted to local climatic conditions. Enhancing livestock productivity, health, and welfare under changing environmental conditions. Promoting sustainable agriculture and rural development by improving the resilience of livestock production systems. To reduce food scarcity and ensure food security, this initiative provides strategies for the policymakers to help their breeders and provide them with a suitable environment for this purpose. Climate-smart livestock management is crucial for sustainable agriculture, given the significant role livestock play in providing essential protein and dairy products globally. To address environmental concerns, practices such as rotational grazing are promoted, allowing for land recovery and reducing overgrazing, soil erosion, and greenhouse gas emissions. Sustainable feed sources like grasses and legumes are encouraged to minimize the carbon footprint of livestock production (Giro and Kumar, 2022).

The most common breed of cattle in the dairy industry is the Holstein-Friesian, which is valued for its high milk output and climate flexibility. All across the nation, dairy farming is common, with Ontario and Quebec producing the most milk. To preserve product integrity and guarantee consumer safety, Canada has imposed stringent rules and quality control methods in the dairy farming industry. Modern management techniques and technology used in livestock farming in Canada are designed to maximize output while reducing negative environmental effects. To increase productivity and lower the industry's carbon footprint, sustainable techniques like genetic modification programs, waste management, and rotational grazing are frequently used. (Government of Canada. 2021)

Eight million Pakistani households have livestock, which provides about a third of their total income (Rahul, Ali, 2018). In addition, a third of the country's workforce is employed in the agricultural industry, providing food and raw materials for the industrial sector (Hussain, Rehman, 2022). Livestock production might be boosted by using cutting-edge technology to manage climate-related disasters and qualms (Abbas. Q., Han J., Adeel. A., Ullah. R., 2019). Food availability can be improved, poverty can be reduced, rural livelihoods can be supported, and environmental sustainability can be maintained by implementing these measures. Despite this, Pakistan's use of environmentally friendly farming practices and technology is still far below the proposed level (Faisal.M, et al., 2021) Due to ineffective climate policy and a lack of financial capacity, the current support system for CC adaptation and mitigation is dreadful (Fahad. S, Wang. J, 2018). As a result, the livestock sector must have an integrated policy to cope with CC variability.

Literature Review:

Holstein-Friesian (HF) cattle, often referred to as Holsteins, are one of the most popular dairy breeds worldwide due to their exceptional milk production capabilities (Hayes et al., 2008). Originating from the Netherlands and Germany, HF cattle are recognized for their distinctive black-and-white coloration and large frame size (Boichard et al., 1997). They exhibit excellent milk-producing traits, including high milk yield, good udder conformation, and efficient feed conversion efficiency (Miglior et al., 2017). The breed's adaptability to various management systems and environmental conditions makes it widely favoured by dairy farmers globally (Berry et al., 2014).

Vulnerabilities to Climate Change Stressors

Despite their widespread use in dairy production, Holstein-Friesian cattle are susceptible to various climate change stressors that can adversely affect their health, productivity, and welfare. Heat stress is a significant concern for HF cattle, as they are highly sensitive to elevated temperatures and humidity levels (Collier et al., 2008). Heat stress can lead to reduced feed intake, decreased milk production, impaired reproductive performance, and increased susceptibility to diseases such as mastitis and lameness (St-Pierre et al., 2021).

Moreover, severe weather conditions such as heat waves and storms might worsen the detrimental effects of heat stress on herd immunity (HF) in cattle (Hahn et al., 2009). Table 1 (Tg &Agropecuarias, n.d.) illustrates the variation in milk output and composition caused by climatic conditions (sun radiation, relative humidity, and maximum and minimum temperatures).

Table 1 Variation in milk output and composition caused by climatic conditions

Breed	Holstein Friesian % Variance
Milk yield	2.58
Fat	5.05
Protein %	8.91
Fat yield	4.77
Protein yield	6.33
Protein/ Fat	1.73

Holstein cattle can typically tolerate temperatures between 25 to 260 degrees Celsius, but to sustain milk production over this range, particular farm management techniques must be used (Berman et al., 1985). According to (West, 2003), the milk output in Holstein cows is 97% of normal production when the temperature is 290 C and the humidity is kept at 40%. However, the yield drastically drops to 69% of normal yield when the humidity climbs to 90%. (Suriya, 2021; Adhikari, Sharma, and Sahrama).

Holstein reduces milk production in moderate and severe situations, according to THI values (which range from 72-78, 79-90, and greater than 90), and are classified as mild, moderate, and severe (Smith et al., 2013).

Table 2 Holstein decreases milk production in moderate and severe conditions.

Breed	**Holstein**		
Stress condition	Mild Stress	Moderate Stress	Severe Stress
Milk Yield	34.8	32.9	30.4
FCM(kg/d)	34.2	33.7	31.1

Importance of Climate Resilience Traits in Holstein-Friesian Cattle

The importance of climate resilience traits in Holstein-Friesian cattle cannot be overstated in the context of climate change adaptation and sustainable livestock production. Climate-resilient traits, such as heat tolerance, disease resistance, and feed efficiency, play a crucial role in enhancing the adaptive capacity of HF cattle to changing environmental conditions (Roth et al., 2020). Selective breeding programs aimed at incorporating climate resilience traits into HF cattle populations have been increasingly recognized as essential strategies for mitigating the adverse effects of climate change on dairy production systems (Berry et al., 2016). By breeding for climate resilience, dairy farmers can reduce the vulnerability of HF cattle to heat stress, improve their overall welfare, and enhance the sustainability of dairy farming operations in the face of climate variability (Pryce et al., 2014).

Climate-Smart Breeding Practices: Canada Perspective

The Holstein cow originated in the Netherlands. The first Holstein-Friesian cow to come to North America was imported from Holland to the United States in 1881. That same year, Holsteins made their way into the pioneer herd of Michael Cook and Son of Aultsville, Ontario. Herman Bollert of Cassel, Ontario, bought foundation stock from Cook in 1883. The vast majority of Holsteins in Canada today are traced to two animals owned by Bollert: Tidy Abbekerk and Aaltje Posch 4th. A depression forced Bollert to disperse his herd in 1896 and many fellow breeders purchased his superior cattle, furthering Holstein genetics across Canada. In 1924, T.B. Macauley of Mount Victoria Farms (Montvic) of Hudson, Quebec, acquired some of the same seed stock from James Rettie and Alfred Hulet in Ontario's Oxford County. Animals from this superior Montvic herd would have a lasting impact on the Holstein breed in Canada as many of these animals are the descendants of the animals found in Canada's Holstein Herdbook today. While some breeders were sceptical of the blacks and whites in the early years, the Holstein proved her worth and became popular during the depression years when the economics of feed conversions were critical. Holsteins have outstanding milk production. They have colour markings of black and white or red and white. (Canadian Government, 2015)

Canada adopts cross-breeding techniques to enhance not only productivity but also to have long-term economic benefits via sustainability. It focuses on maximizing the health of the Holstein and cross-breeding them with other farming species to make them more resilient to tolerant harsh weather. Home to approximately 41% of Canada's dairy farms, Quebec's dairy industry is characterized by smaller, family-run farms. The province is known for its diverse range of dairy products, including fiHo cheeses. Quebec's climate, with cold winters and warm summers, necessitates specific farming practices, such as the use of insulated barns and strategic feeding regimes to maintain production year-round. Contributing significantly to Canada's milk production, Ontario's dairy farms are typically larger and more commercially oriented. The region benefits from relatively milder weather, allowing for a variety of farming practices, including both indoor and pasture-based systems. (Neethirajan,2024)

Moreover, Artificial insemination programs are widely used in the dairy industry, and accurate estrus detection is crucial for successful breeding. However, factors such as herd size, animal density, and limited staff can make estrus detection challenging. To overcome this, hormonal synchronization protocols, known as timed AI (TAI) protocols, are used to predict ovulation time. A recent study on Canadian Holsteins found that 60% of studied herds used TAI in 2017, with approximately 20% of all animals on TAI. However, TAI has been found to potentially introduce bias in genetic breeding programs, as it masks an animal's true fertility performance. This can affect the accuracy of genetic evaluations of fertility traits, as demonstrated in simulation studies and on-farm data. Canadian livestock farms are equipped with modern technologies to enhance the climate resilience of this species and increase its productivity. (Alcantara et.,al.2022)

Genetic diversification

Genetic Evaluations are provided by CDN for seven dairy breeds (Holstein, Ayrshire, Jersey, Brown Swiss, Canadienne, Guernsey, and Milking Shorthorn). All animals receive a genetic evaluation for a complete series of traits in production, conformation, and Functionality. All genetic evaluation calculations in Canada use a methodology called the "animal

Model", which refers to the goal of estimating each animal's genetic merit. The genetic evaluation of each animal is based on contributions from four possible sources: parents, performance, progeny, and DNA (genotype). When an animal has no performance, no progeny, or no DNA, we, therefore, rely on the average of his parent to evaluate its genetic potential and calculate its genetic merit or Parent Average. An animal's Parent Average continually evolves as the sire, dam, and/or older ancestors in the pedigree add performance data on themselves as well as on existing and new progeny. The major contributing source of information for estimating an animal's genetic merit is the performance of their progeny. It is then an "ultimate test" to know how good an animal is at transmitting its genetic potential. For cows, their performance (classification and production records) also count but at a lower extent. For animals that are genomically tested, the DNA contribution is ADDED to the information available; it does not replace any source of information. When information is added, the reliability of the genetic evaluation usually increases.

There is a tiny population of crossbred animals that are the result of mating Canadian Holstein dams to sires of different breeds. A portion of the surge in interest has resulted from a planned crossbreeding initiative known as The Two-Plus Project, which pairs Norwegian Red (NR) sires with Holstein (HO) dams. Approximately seventy cooperating herds agreed to breed their Holstein cows to nine NR sires and to nurture the crossbred heifers for at least one full lactation. Because of its many years of breeding for better health (mastitis) and fertility, the Norwegian Red breed was chosen [6]. For the same reasons, the Swedish Red (SR) was brought to Canada. Data files for production, conformation, and reproduction were obtained from Canadian Dairy Network (CDN) databases. The last updated data from CDN were received in March of 2011 with the latest test day date of January 21,2011.

As anticipated, all of the crossbreds produced far less milk than Holsteins, with yields varying from -240 kg to -880 kg in the first lactation to -145 kg to -654 kg in the third.(even though there were few animals and records during the third lactation) (Table 3).

Table 3 305-d Milk Production, kg compared to Holstein Sire Breed Average

Breed	Item	1st Lac	2nd Lac	3rd lac
BS	Cow	189	76	30
	Sire	48	28	14
	TD record	1358	520	134
	Est. Diff	-358	-442	-184
	SE	38	46	44
JE	Cows	314	96	19
	Sires	72	30	12
	TD record	1968	495	75
	Est.Diff.	-880	-996	-264
	SE	24	27	26
NR	Cows	589	300	89
	Sires	9	7	6
	TD record	4208	1838	345
	Est. Diff.	-240	-885	-145
	SE	20	24	23
SR	Cows	76	28	10
	Sires	3	2	2
	TD records	519	184	39
	Est. Diff.	-353	-893	-654

	SE	47	49	52
HO	Cows	25,026	10,014	2781
	Sires	2205	1314	623
	TD records	177,518	64,184	12,389

Thus, cross-breeding and breeding have their effects on the production rate of Holstein. The seasonal variation also influences the productivity of Holstein friesies. Together with intensive selection, the development of intensive dairy systems has been developed by innovations and technological breakthroughs, among which conventional genetic selection played a major role over the past decades (Miglior et al., 2017). Yet, the strong focus of the dairy industry on ensuring food security through higher productivity raises concerns about other sustainability dimensions (Clay et al., 2020). This situation requires a new breeding strategy, the simultaneous selection of productivity, and functional traits such as adaptation, welfare, and resilience.

Technique to Mitigate Climate Stress in Holstein Cattle

Genetic selection:

The long-term sustainability of the dairy cattle industry depends on the development of balanced breeding goals to simultaneously improve animal health and welfare, productive efficiency, environmental impact, food quality, and safety while minimizing the loss of genetic diversity. In Canada, the temperate climate with distinct seasons influences HF cattle's milk production. While cooler temperatures and ample pasture during the spring and summer months typically result in optimal milk yields, harsh winter conditions can lead to reduced forage availability and increased energy expenditure for cattle, impacting milk production. Additionally, heat stress during hot summer months can also negatively affect milk production, as HF cattle are susceptible to heat-induced stress, leading to decreased feed intake and milk yield.

Forage management practices, including rotational grazing and forage conservation techniques, are integral to ensuring consistent feed availability for HF cattle throughout the year, particularly during winter months. Research by Brown et al. (2019) emphasized the importance of rotational grazing in maintaining pasture quality and quantity, thereby optimizing nutrient intake and milk production in dairy cows. Furthermore, studies by Jones et al. (2021) highlighted the effectiveness of forage conservation methods such as silage and haylage production in extending the grazing season and mitigating feed shortages during periods of inclement weather.

Multi-climate Sheds

Multi-climate sheds, embodying advanced climate-smart technologies, represent an innovative and adaptable approach to modern dairy farming. These specialized structures are adept at adjusting to a range of weather conditions, thereby ensuring anindoor environment that maintains optimal conditions for dairy cattle (Galama, Ouweltjes, Endres,2020; Kumar, Thakur, 2022). The incorporation of sophisticated systems for regulating temperature, humidity, and air quality within these sheds is vital for the health and productivity of the cattle. Research has indicated that variations in ambient temperature can significantly influence the metabolic rate of cattle, as well as their feed intake and milk production capabilities (Liu, Li, Chen, Lu, Wang, 2019).By offering a controlled and stable microclimate, Multi-climate Sheds play a crucial role in mitigating the physiological stress experienced by cattle due to temperature fluctuations. This not only enhances the overall welfare of the animals but also potentially leads to more consistent and increased dairy yields.

Holstein in Pakistan:

Pakistan is gifted with a large livestock population. The national herd consists of 33.0 cattle, 29.9 buffaloes, 27.4 sheep, and 58.3 goats in a million. The productivity of animals in Pakistan is generally low and needs to improve (GOP,2010). The main reasons for the low productivity of farm animals are; non-descript breeds, poor management, lack of nutrition, lack of resources, low inputs; inadequate artificial insemination service, and diseases. These causes lead to low average milk production, late age of first calving, delayed conception, impaired fertility, and long calving intervals (Khan et al., 2008; Ali et al., 2011) Holstein Friesian cows are well known for their high milk yield. They are getting popular in the commercial dairy sector of Pakistan. In recent years, to meet the increasing demand for milk, the government expected the import of exotic breeds of dairy cattle in the country with the intention of either rearing as purebred or upgrading the indigenous non-descript cattle. Holstein-Friesian was the main dairy breed imported for this purpose. Several physiological and environmental factors can significantly influence the productive potential of these animals in tropical and sub-tropical environments. These imported exotic dairy cattle are maintained in order to increase milk production. Holstein-Friesian has the genetic potential to produce high milk production. (Sandhu, Tariq and Khan,2011)

Breeding practices in Pakistan

The breeding options adopted by the farming industry of Pakistan include:

1- **Pure Breeding Of Indigenous Cattle**
   The genetic variety and robustness of Pakistani HF cattle herds are enhanced by the presence of indigenous cattle breeds like Red Sindhi and Sahiwal. Farmers create locally adapted HF crossbreeds that are suitable to the current climate difficulties by incorporating traditional knowledge and indigenous breeding procedures (Ali et al., 2021).
2- **Replacement of Local Cattle With Exotic Cattle.**

The influx of information on social media sometimes leads us to believe that if our local cattle are not meeting the demand for milk and meat then these should be replaced with more productive exotics. Replacing all cattle with exotics may be theoretically possible but practically replacing 50 million cattle is not a feasible option. Gradual replacement is possible and it is happening with the passage of time. Importing of exotic dairy cattle in Pakistan started in the early 80s when Holsteins from America and Europe were imported into the private sector. Government-supported nucleus herds, one each in Punjab, KP and Balochistan. The main objective of these nuclei was to produce cheaper semen for upgrading indigenous breeds. Later imports in the 90s and till today resulted in a mixed experience. Animals with smallholders generally fail to survive and breed further but organized farms have some success stories. At present, there are about half a million imported cattle in the country and about 10000 cows are being imported every year. A million doses of exotic semen are imported to cater to the need of exotic farms, for crossbreds and crossbreeding non-descripts. The performance of imported cows with private setups has been obscure. (khan,2022)

3- Cross-breeding with exotic cattle (Genetic selection)

Pakistani dairy farmers use selective breeding methods to improve HF cattle's climatic resilience qualities despite obstacles. To increase the adaptability of HF cattle to local environmental circumstances, breeding programs prioritize qualities such as heat tolerance, disease resistance, and feed efficiency (Khan et al., 2020). The following graph shows the milk yield and length of the lactation period in the year 2004.

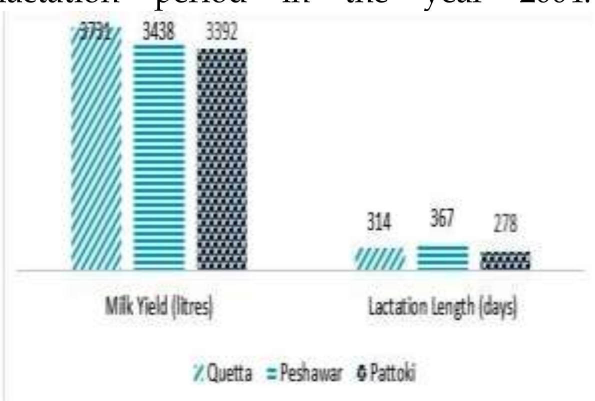

Figure 1 Lactation milk yield and length of Holstein at three government nucleus farms

Crossbreeding is an efficient way to increase a species' genome and productivity. This will strengthen its resistance to climate change, and as productivity rises, more economic advantages and population demands will be addressed. For F1 and F2, the average lactation yield figures recorded were 2052 kg and 1538 kg, respectively. Purebred exotic cattle weighed 2150 kg on average, while native cattle weighed an average of 1049 kg. The calving interval was 450 days for native and purebred exotics, and 422 and 438 days, respectively, for F2 in F1 and F2. In over 50 datasets that were analyzed, it was shown that the F2 was inferior to the F1 in every characteristic. It was reported that heterosis was significant for all variables but lactation duration. (See figure2)

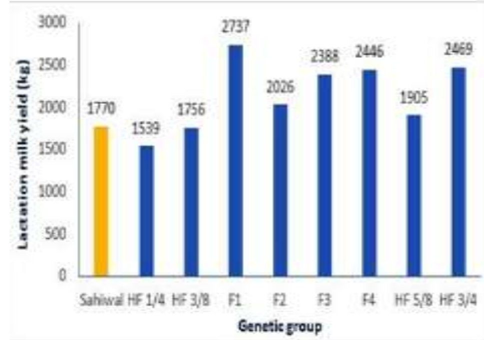

Figure 2 Milk yield in Native, crossbred (Level of exotic inheritance indicted) and exotic cattle

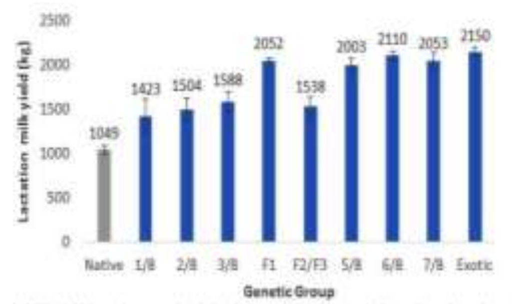

Figure 3 Milk yield in Sahiwal and Holstein crosses in Pakistan (Ahmad et.,al.2001)

4- Upgradation of non-descript

Improvement of "non-descripts": Improving "non-descripts" is the fourth alternative for Pakistani cattle breeding. One choice was to crossbreed exotic cattle with Jerseys or Holsteins with the appropriate amount of exotic inheritance (50–75%) as previously mentioned. The alternative is to replace them with high-producing, regionally accessible breeds like Red Sindhi or Sahiwal, depending on the situation and the breed's availability in a home tract.

Cooling Technique to Mitigate Heat Stress in Holstein Cattle

Since heat stress negatively impacts Holstein production in Pakistan, where summers are harsher than winters, spray cooling—which can be provided in a holding pen or at the feed bunk—is frequently used. It reduces body temperature and respiration rate [1,2] and increases feed intake and milk yield in hot weather. Because of growing concerns over groundwater resource depletion, research in recent years has concentrated on optimizing water use [3-5]. Dairy animals are cooled using a variety of water reduction techniques, such as the impact of sprinkler flow rate [2-4], spray duration [3,6,7], and droplet size. Another tactic for reducing water use could be intermittent cooling sessions (CSs). In Punjab, Pakistan, corporate dairy workers have historically taken daily showers from early in the morning till late at night. According to preliminary survey results, a single Holstein cow needs 840 L of groundwater on average per day to stay cool during the summer (unpublished data). This is a tremendous amount of groundwater utilized to keep dairy cows cool. Table 2 summarises the average temperature, relative humidity, and thermophilia (THI) in the open area and inside the shed. In comparison to the morning, the afternoon's average temperature and THI were 5.3°C and 3.9, respectively, and 2 and 2.6°C higher than the evening's.

In comparison to the morning, the afternoon's average temperature and THI were 5.3°C and 3.9, respectively, and 2 and 2.6°C higher than the evening's. Compared to the evening, the average afternoon outdoor temperature and THI were greater in the afternoon. On the other hand, compared to the inside shed, the morning RH and temperature outside were 2.4% higher and 0.2°C lower, respectively. (Table 4).

Table 4 Summary of the average meteorological measures from August to September 2019

Measures	**Morning**			**Afternoon**			**Evening**		
Inside pen	**Means**	**SD**	**Range**	**Means**	**SD**	**Range**	**Means Range**		**SD**
Temp (C)	27.8	1.4	25.8-29.7	33.1	2.3	27.6-35.6	31.1	1.7	27.8-33.6
RH%	87.2	13.1	55.5-96.9	51.2	11.5	40.9-78.5	62.6	8.7	50.9-77.0
THI	80.2	2.0	77.6-83.3	84.1	5.3	78.5-93.9	81.5	1.6	79.0-83.6
Outside open Area									
Temp (C)	27.6	1.2	25.7-29.6	35.9	2.4	30.6-38.6	31.6	1.4	29.2-33.3
RH%	89.6	6.5	79.0-97.4	47.1	7	308.9-60.4	61.7	9.4	49.3-75
THI	80.4	2.6	76.5-84.0	76.5-84	2.8	79.4-87.8	82.1	1.7	79.6-85

The different treatments significantly affected the physiological responses (Table 5). The cows in the 4CS group had the lowest body temperature (38.7°C) and respiratory rate (63breaths/min), and the highest was recorded in the 2CS group(39.3°C and 79.2 breaths/min; p = 0.000; Table 5). The daily milk yield was 1.1 kg/d more in the 4CS than 2CS group (p = 0.040; Table 5). However, the 4CS and CNT had statistically similar milk yield (11.9 vs 11.0, respectively; standard error (SE) = 0.33 kg, p>0.05). Likewise, the CNT and 2CS also had similar milk yield (11.0 vs 10.8, respectively; SE = 0.33 kg, p>0.05).

Table 5 Effect of different treatments on physiological and production responses of Holstein Friesian cows during summer (n = 21)SEM, standard error of the mean; DMI, dry matter intake; BCS, body condition score.1) CNT, control 11 h continuous cooling with sprinklers from 0700 to 1800 h; 4CS, four cooling sessions from 0700 to 0800 h, 1000 to 1100 h, 1500 to 1600 h, and 1700 to

1800 h; 2CS, two cooling sessions from 0700 to 0800 h and 1500 to 1600 h.2) DMI is for a group of 7 cows per treatment. a-c Values with different superscripts in a row are significantly different (p ≤ 0.05)

Measures	**Treatment**			**SEM**	**p-VALUE**
Physiological Responses	**CNT**	**4CS**	**2CS**		
Rectal Temperature (C)	**39.0**^{0}38.7^{0}	39.3^{0}		**0.05**	**0.000**
RR (breaths/min)	69.9	63.0	79.2	1.79	0.000
Production responses					
DMI (kg/7 Cow)^{2}	80.06	81.93	75.75	3.50	0.003
BCS	2.64	2.77	2.64	0.07	0.322
Weight (Kg)	566.5	597.7	608.8	24.7	0.469
Milk Yield(Kg)	11.0	11.9	10.8	0.33	0.040
Milk Components					
Fat%	4.0	4.2	3.9	0.10	0.170
Protein%	2.9	3.0	2.9	0.05	0.153
Lactose%	4.56	4.80	4.60	0.18	0.130
Total solid%	12.2	12.8	12.2	0.08	0.002

Discussion:

Both countries have their resources and agricultural technologies that are closely linked with their role in promoting the climate-smart breeding of Holstein. Canada being a developed country has adopted a wide range of initiatives especially cross-breeding technology to make the cows climate resilient and to enhance their productivity by combining g the genomes of various species. The Canadian Holstein breed has developed under a philosophy of balanced breeding and cutting-edge research. While many countries have followed the route of single-trait selection, the Canadian cow has been perfected for a balanced combination of type, production, and health traits. The Canadian cow is known for traits related to longevity and profitability, such as sound feet and legs, dairy strength, and a desirable udder. Canadian Holsteins are built to withstand high milk production for a long and trouble-free life.

On the other hand, Pakistan is far from these types of initiatives, although there are some advanced technologies available in the framing industry still there is a lack of resources that make them work proficiently. Pakistan has particular difficulties in implementing climate-smart breeding methods because of its restricted access to genetic technologies, poor infrastructure, and low resources. But there are chances to improve climate resilience in HF cattle herds by utilizing traditional breeding techniques and indigenous knowledge (Malik et al., 2019). Animal breeding is the leading sector in the agricultural department of the country. the list of indigenous, exotic, and crossbred species is a little different from the developed nations. The existing production of the herd is comparatively low than the genetic potential of the breed which may be due to ill-management and haphazard breeding practices. Pakistan offers a wide range of climate-smart technology. However, few farmers use these tools primarily due to their lack of technical expertise, restricted investment capacity, and ignorance of the advantages and accessibility of this technology. There was a significant sire effect which indicates the possibility of improving the existing stock through selective breeding.

There are clear disparities in the goals, priorities, and difficulties associated with raising HF cattle between Pakistani and Canadian programs. To improve climate resilience in HF cattle, Pakistan uses traditional breeding techniques and indigenous knowledge, while Canada benefits from cutting-edge genomic technologies and research infrastructure. Opportunities for knowledge exchange and cooperative research projects between the two nations present encouraging paths toward enhancing climate-smart breeding methods and guaranteeing the long-term sustainability of HF cattle production globally.

Conclusion:

To sum up, the study of climate-smart livestock breeding methods for Holstein-Friesian cattle in Pakistan and Canada highlights the significance of adaptive measures in reducing the effects of climate change on dairy production. While Canada places a great focus on cutting-edge cross-breeding and genomic technology, Pakistan struggles with a lack of resources and infrastructure. Nonetheless, traditional breeding practices and indigenous knowledge present promising paths toward improving Pakistani Holstein-Friesian cattle's resistance to climate change. Cooperation between the two countries might promote innovation and knowledge exchange, improving cattle output and adaptability to changing climate circumstances. climatic-smart breeding techniques can be accelerated by collaborating the strengths of both nations and by supporting collaborative research projects. This will guarantee robust and sustainable dairy production systems in the face of persistent climatic threats.

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