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TECHNOLOGY ADOPTION AND SUSTAINABLE SMALLHOLDER DAIRY PRODUCTION:

A CASE OF THE PRIVATE SECTOR'S CONTRIBUTION, BANGLADESH

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Abstract

Purpose: This study aims to assess the impact of technology adoption on sustainable smallholder dairy production under contract farming as opposed to non-contract farming.

Materials and Method: The research used a cross-sectional quantitative method. Smallholder dairy farmers from two north-western agro-ecological regions of Bangladesh completed a 35-item (15 demographics and 20 IVs-DV related) structured survey questionnaire, which examined how technology adoption affects sustainable dairy production and the contribution of the private dairy processor in this relationship. Out of 100 purposive samples, 50 were under contract farming, and 50 were without a contract.

Results: Breed, feed, and cellphone networking were considered technology adoptions (IVs) against sustainable dairy production (DV). Six hypotheses were tested to find the relationship between variables in each option. Adoption of three technologies ($BTA \rightarrow SDP = 0.012 < 0.05$), ($FTA \rightarrow SDP = 0.033 < 0.05$), ($CPN \rightarrow SDP = 0.037 < 0.05$) under contract farming are all significantly related, while for non-contract farmers, only cellphone networking is significantly related ($BTA \rightarrow SDP = 0.791 > 0.05$), ($FTA \rightarrow SDP = 0.275 > 0.05$), ($CPN \rightarrow SDP = 0.017 < 0.05$). It reflects that technology adoption under contract farming is better than non-contract farming.

Conclusion: Technology adoption is crucial for smallholder sustainable dairy production. Technology costs money, and impoverished farmers need support from stakeholders. The private dairy processor can support these farmers with technology adoptions. The findings of this study support contract farming and can be used as a model for others. It also benefits the dairy industry, academia, researchers, and policymakers.

Keywords: Technology Adoption, Smallholder dairy farmers, Private processors, Non-contract farmers.

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1. Introduction

Bangladesh is an agrarian country, densely populated, and ranked 9th globally. The total population is 165 million (8th largest worldwide) in an area of 148,460 square kilometers (57,320 sq mi), ranked 92nd in the world. The Population growth is 1.08% yearly as of 2022. Bangladesh might reach 300 million by 2050 (BBS, 2020) if replacement fertility is fulfilled. Global growth projection is from 8 current to 9.7-10 billion by 2050 (Burrow et al., 2021; Sadigov, 2022).

Agricultural productivity must rise 60% from 2005-2007 to fulfill food demand. Bangladesh is no exception. Livestock, particularly dairy, is crucial for nutrition, protein, and vitamins. The global shortage of milk, including in Bangladesh, exists now and future-at least for the next five decades) (Tomar et al., 2013).

Despite producing 70%–80% of milk, smallholder farmers require more (Datta et al., 2019). Poverty limits farming (31.5% below subsistence, 75% poor, living on US $1.25 a day (Pomi, 2019; Sultana et al., 2020). Thus, stakeholders must address these problems (Mukherjee et al., 2020; Rahman & Habib, 2021). Private dairy processors provide affordable technology and services. It ensures sustainable Dairy Production (SDP).

Dairy farming is a significant segment of livestock in Bangladesh. Dairy animals include cattle (25.7 million), goats (14.8 million), buffalo (0.83), and sheep (1.9 million) (BBS, 2020). It is a primary agricultural sector (Antor et al., 2020) and a GDP contributor (1.60% in 2017) (Alam et al., 2022; BBS, 2020; Miah et al., 2020; Uddin et al., 2011). It generates approximately 41% of the total labor force, representing 365-day jobs (Alam et al., 2022; Quddus, 2018; Rahman et al., 2003), improving rural livelihood and providing nourishment, protein, and a nutritious diet for everyone (Jabbar & Raha, 1984). However, half the nation lives in poverty. Thus, they lack 2122 kcal per day (MoF, 2018). Dairy can contribute to nutrition, protein, employment, and industrial input.

Smallholder dairy farming (SDF) is defined based on geography, size, and intensity (Morton, 2007; Nyambo et al., 2019). However, simplistically, SDF is a family-run farming (husband, wife, and grown children) (Garner & de la O Campos, 2014) with 3-5 cattle (Swai et al., 2014), modest resources or capital (OECD, 2012), and located on the same premise to produce milk for primarily for Sale and own consumption. 80% of smallholders are rural, and 75% of farmers are small and poor, earning Tk. 8,714 (US $85.64 current conversion) a month to cover their living expenditures in 2017 (Labor Force Survey, 2017; Sultana et al., 2020). They have 85-90% indigenous and 10-15% of crossbred cattle produce subsistence dairy output (Faruque et al., 1990; Habib et al., 2017). Although smallholder farmers have 75-80% of Bangladesh's total milk (Uddin et al., 2022), the supply is still insufficient to meet the growing population and subsequent reasons (166.5 million as of July 1, 2019) (BBS, 2020).

The development of dairy production is inevitable to meet the extended demand for milk. Although dairy production is barely profitable, farmers can increase production output by adopting advanced technology, including breeding technology, feeding technology, labor (Skider et al., 2001), cell phone use for networking (Dipu et al., 2019; Kabbiri et al., 2018; Maina, 2015), a business partner (processor) (Haq & Raju, 2022; Husain & Amin, 2017; Uddin et al., 2022), and advanced knowledge and know-how (Maleko et al., 2018), high yield GM grazing (Hyland et al., 2018). However, many more technological advances like automated feeding and milking, waste management, biogas system, automatic temperature, disease sensors, etc. Furthermore, Edge Computing (EC), the Internet of Things (IoT), and Distributed Ledger Technologies (DLT) are also used in urban dairies (Alonso et al., 2020).

There is a significant correlation between dairy development and technology adoption. In Bangladesh, farmers get assistance from the government, cooperatives, NGOs, and industrial dairy processors. Policy, research, and development campaigns are mostly government responsibilities. Similarly, non-governmental organizations (NGOs) work to promote microcredit, advocacy, artificial insemination, supplementary feed, and treatment, generally on a project basis. At the same time, cooperative societies educate their members about the production process, clinical support, and supply chain (Sims, 2021). But the industrial dairy processors assist them in all farming respects. Producers of milk do business through contract farming. They either help farmers find suitable agro-zones or increase milk output in the area. Under certain situations, they contract smallholder farmers to produce milk. They provide comprehensive extension services, including animal husbandry, breed, feed, procurement, and supply chain, and encourage smallholder farmers to join. Farmers produce milk only for the corporation. If the milk passes quality checks, the company buys back 100%. The firm guarantees payment, transparency, and pricing (Islam et al., 2019; Meseret et al., 2022).

Contract farming is an institutional agreement between a smallholder farmer and an industrial processor (Das et al., 2021). It is widely used in agriculture, livestock, dairy, and poultry. The purpose is to connect rural farmers to the market and secure the back-end linkage of the dairy processor to meet the increasing demand for dairy products.

Studies reveal that contract farming increases income and lowers poverty (Minten et al., 2009; McCulloch and Ota, 2002; Minten et al., 2006; Maertens and Swinnen, 2009; Warning and Key, 2002; Singh, 2002; Miyata et al., 2009; Morrison et al., 2006). Key and Bride (2008) examine the effects on productivity, farm profit (Narayanan, 2014), efficiency (Ramaswami et al., 2006; Begum et al., 2012), women's empowerment (Singh, 2002; Raynolds, 2002), domestic and global chain linkage (Glover and Kusterer, 1990), reduction of imperfect markets and processing fees (Key and Runsten, 1999; Hellin and Higman, 2003), credit access, management skills, technology, market access (Hennessey & Lawrence, 1999; Rhoades, 1995; Fukunaga and Huffman, 2009).

Agricultural production involves risk and uncertainty (Mishra & Sandretto, 2002; Moschini & Hennessy, 2001). It is risky due to external factors (Mishra & Sandretto, 2002), which may damage productivity and incur significant losses (Drollette, 2009). Thus, farmers must understand risks, uncertainties, and mitigation strategies (Ullah et al., 2016).

Private dairy processors engage with competent smallholder farmers for milk production. To join, a farmer needs at least a minimum number of cows. Smallholders manage farming for milk production, following the guidelines of the processor. In exchange, the processor gives free training, clinical assistance, reduced-price feed, artificial insemination, and a 100% buy-back policy. Terms and conditions violations allow any party to cancel the contract (Begum et al., 2013; Das et al., 2021; Islam et al., 2019).

However, researchers also argue that contract farming is a means of exploitation, economic disparity, dependence, and poverty of small-scale producers by agro-industrial firms, despite the evidence showing smallholders' successful participation in contracts (Islam et al., 2019). Based on a thorough literature analysis, researchers conclude that contract farming helps drive the processes of social divergence and capital growth processes. It causes economic disparity, dependence, and poverty (Das et al., 2021).

Smallholder dairy farming in Bangladesh has two methods: independent (without a contract) and registered members under a contract with a cooperative society or private dairy processors. Independent farmers produce milk without any legal bonding with any third party. They sell milk to the open market at an agreed-upon price. They take risks in production, output, and supply chain. They seek animal healthcare and professional services that are accessible locally on payment. The majority of them learn by doing or from their fellow farmers.

Regarding cooperative society, the BMPCUL is the central union, and its village-level organization is the Primary Milk Producer's Cooperative Society (PDUSS). It has 100–400 dairy farmers from 3–6 villages. Farmers must own a milking cow and pay Tk 10.00 for a share, Tk 1.00 for an entry fee, and Tk 1.00 for a thrift deposit to join a village primary organization. Farmers must also give 150 liters of milk every year to keep membership. Each farmer must supply 150 liters of milk 150 days a year. Farmers may borrow from thrift deposits. PDUSS must buy one share of central society BMPCUL for Tk1000 and supply 1000 liters of milk within 180 days. The central society also deducts Tk 0.20 per liter of milk members sell for services such as bovine development, treatment, development programs for milk collection facilities, veterinary services, artificial insemination services, balancing livestock feed, and cow purchase loans. Each society has a collection center where members donate milk twice daily to the nearest one. (Islam et al., 2019; Jabbar et al., 2005; Zaedi et al., 2009).

Bangladesh has 14 organized dairy processors, Milk vita, BRAC, and PRAN, which dominate the market (Alam et al., 2022; Haque, 2009). They have contractual arrangements to help milk producers (Jabbar et al., 2007).

PRAN started a dairy business named PRAN Dairy Limited (PDL) in 2004. It is the third largest (10% of the market) dairy processor in Bangladesh. PDL began by producing UHT (ultra-high temperature) milk for the School Nutrition Program. It started the milk project with help from Land-54 O-Lakes, Tetra Pak, and the USDA.

PDL has milk collection centers in eight districts of Bangladesh. It is the role model of contract farming. Under this contract, PDL professionals supervise farmers' dairy farming. They advise and provide farmers with free veterinarian services, including animal husbandry, dairy housing, procurement, business, pricing, and women empowerment. Before accepting it, PDL technicians test milk for quantity and quality, including water, fat, bacteria, and acidity content. The price of milk is determined by its fat content. Lower the fat, lower the price, and vice versa. PDL buys 100% of farmer's milk that passes quality standards.

This research studied the technological adoption and its impact on sustainable dairy production under contract farming, compared to independent (without contract) farming. The study has considered PDL as a case.

2. Problem Statement

The world population is rising so is the demand for milk (Clay et al., 2020; B. R. Singh et al., 2020; Tripathi et al., 2019). It threatens food security (Henchion et al., 2021; Tucker, 2014) and impacts water, forestry, energy, and socio-economic problems (Sadigov, 2022). So, excessive milk production is required (Datta et al., 2019), and adopting advanced technology is the solution. However, impoverished farmers struggle to adopt technology owing to primitive farming (Akbar et al., 2020). Stakeholders must help farmers overcome these challenges (Mukherjee et al., 2020; Rahman & Habib, 2021). Under contract farming, the private dairy processor can enhance technological adoption. It will help the processor satisfy the raw milk supply chain and prolong milk demand.

This study hypothesized that a partnership between farmers and private dairy processors would be an effective means of technology adoption for achieving sustainable dairy production in smallholder farming as opposed to operating a dairy farm on one's own. This research gap is a new way to look and would be a great addition to the research world for further study.

3. Objectives of the Study

The overall objective is to compare the relationship between technology adoption (breed, feed, and cellphone networking) and sustainable dairy production under contract and non-contract smallholder dairy farmers in Bangladesh.

Specific Objectives

Contract Farmers

SO1 To assess the relationship between breeding technology and SDP under a contract farming with a private dairy processor.

SO2 To evaluate the relationship between feeding technology and SDP under a contract farming with a private dairy processor.

SO3 To examine the relationship between cellphone networking and SDP under a contract farming with a private dairy processor.

Non-Contract Farmers

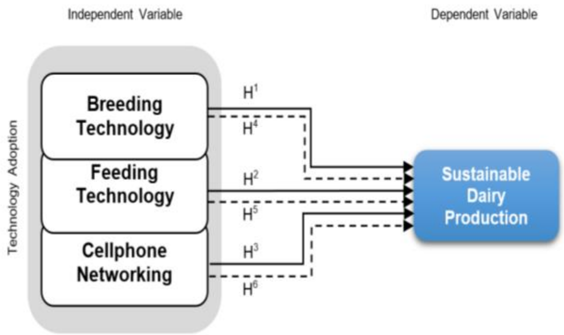
SO4 To assess the relationship between breeding technology and SDP of non-contract farming.

SO5 To evaluate the relationship between feeding technology and SDP of non-contract farming.

SO6 To evaluate the relationship between cellphone networking and SDP of non-contract farming.

4. Conceptual Framework and Hypotheses

This research investigates whether contract farming facilitates the adoption of technologies necessary for sustainable dairy production. The following model navigates the conceptual framework (Figure 4.1).



re 4.1 Conceptual Framework Contract (⟶) and Non-contract Farmer (- -▸)

This research has drawn six hypotheses as follows:

Farmers with contract farming

H1 Breeding Technology Adoption (BTA) has a significant relationship with SDP under contract farming. (BTA→SDP)

H2 Feeding Technology Adoption (FTA) has a significant relationship with SDP under contract farming. (FTA→SDP)

H[3] Cellphone Networking (CPN) is significantly related to SDP under contract farming. (CPN→SDP)

Farmers without contract farming

H[4] Breeding Technology Adoption (BTA) is significantly related to SDP under non-contract farming. (BTA→SDP)

H[5] Feeding Technology Adoption (FTA) has a significant relationship with SDP under non-contract farming. (FTA→SDP)

H[6] Cellphone Networking (CPN) is significantly related to SDP under non-contract farming. (CPN→SDP)

5. Material and Method

This study was a cross-sectional quantitative survey. It was conducted in two Bangladeshi agro-ecological districts (Pubna and Shirajgonj), where the total population was 1828 contract and 310 non-contract smallholder dairy farmers were available in two districts. The targeted population was 210 contract and 70 non-contract farmers. Only 10 years plus experienced farmers were considered. The researcher used purposive sampling based on the judgment of saving time, money, and operational feasibility (Black, 2019; Campbell et al., 2020). 100 (50 contractual and 50 non-contractual) farmers from neighboring villages were selected. The researcher collected data individually through person-to-person farm visits.

The structured questionnaire (Bengali version) comprised 35 items, where 15 questions represented demographics and 20 on independent and dependent variables. The study questions were carefully crafted to data concerning aspects and the study's objective. The questionnaire was peer-reviewed by research experts. The items were incorporated from related previous studies (Dipu et al., 2019; Kabir et al., 2022; Mamun-ur-Rashid et al., 2019; Quddus, 2013; Quddus, 2022; Richards et al., 2019; Sarker et al., 2020; Uddin et al., 2022). 5 point Likert scale (1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree) was used to collect data on various items. The researcher contacted 150 farmers, and 110 (73.33%) were interested in the survey. 110 were interviewed, and 10 respondents were discarded due to their incomplete answers. All the surveyed farmers had at least 10 years of experience (Nazera & Raju, 2022).

There are two study groups, private dairy company-assisted technology adoption in breeding, feeding, and cellphone networking. Conversely, self-assisted technology uses in the same areas.

The statistical analysis was conducted using the SPSS (26.0 version) (software program for the social sciences). Adopters under contract and non-contract were characterized using contingency tables (cross-tabulation) to examine percentages of each group concerning a given factor. The study also used SmartPLS (v.3.2.8) to analyze, using the Path Coefficient to test the hypotheses' relationships to justify the significance of the options mentioned in this study.

6. Analysis and Results

6.1 Descriptive Statistics

Table 5.1 shows the demographic information of 15 items split into contract and non-contract farmers. There are 50 (100%) males in contract and 40 (80%) males, and 10 (20%) females in non-contract groups. There are 15 (30%) older farmers aged 51 and over) and 1 (2%) younger farmer aged 21-30 in the contract group, whereas 23 (46%) older farmers and

2 (4%) younger farmers, respectively, are in the non-contract group. 32 (64%) contract farmers and 30 (60%) non-contract farmers have elementary schooling. 36% of farmers have no education, vs. 18% of non-contract and contract farmers. 40 contract farmers (80%) have between 10 and 14 years of experience, while 32 non-contract farmers (72%) have the same experience. Medium-sized farms comprise most of both groups, with 30 (60%) vs. 16 (32%). 28 (56%) of contract farmers' cattle are 6-10, while 33 (66%) are 1-5. 88% (44) of cows are hybrid, compared to 34% (17) for contract and non-contract farmers, 43 (86%), and 10 (20%) Friesians, respectively. Total milk production per day per cow falls between 21-40 liters accounting for 21 (42%), contrary to 11 (22%) under 21-40 liters. 30 (60%) vs. 15 (30%) contract and non-contract farmers make money from dairy only. 23 (46%) contract farmers earn less than Tk. 500,000 per year, while 37 (74%) are non-contract farmers. 100% (50) contract farmers treat their cattle regularly, but only 70% (35%) of non-contract farmers do the same. Only 20% (10) and 8% (4) rarely do the same. In the same way, 90% (45) of contract farmers regularly vaccinate their cows, while only 84% (84) of farmers without contracts do so. Finally, 60% (30) of contract farmers fed their cows processed feed, 8% non-processed feed, and 32% (16) both. In contrast, 20% (10) of non-contract farmers fed their cows processed feed, 70% (35), non-processed 70% (35), and both 70% (35). 60% (30) and 32% (16) of contract and non-contract farmers have Smart Phone, respectively. In contrast, 26% and 60% have regular Phones.

6.2 Assessment of Structural Equational Model

Hypotheses (Path Coefficient)

Contract Farming

H[1] Breeding Technology Adoption (BTA) has a significant relationship with SDP under contract farming. (BTA→SDP)

The outcome reveals that the path coefficient between BTA and SDP is 0.438. The *t* value is 2.607, which is higher than the value of 1.96 (significant as 2.607>1.96). Similarly, the *p*-value of 0.012 is lower than the threshold value 0.05 (significant 0.012<0.05). There is a significant relationship between BTA and SDP. So, H[1] is acceptable.

H[2] Feeding Technology Adoption (FTA) has a significant relationship with SDP under contract farming. (FTA→SDP)

The result shows that the path coefficient between FTA and SDP is 0.438. The *t* value is 2.144, greater than the threshold of 1.96 (significant as *t* 2.144 >1.96). The P-value of 0.033 is lower than the threshold value 0.05 (significant 0.033 < 0.05). So, there is a significant relationship between FTA and SDP. So, H[2] is acceptable.

H[3] Cellphone Networking (CPN) is significantly related to SDP under contract farming. (CPN→SDP)

The result reveals that the path coefficient between CPN and SDP is -0.350. The *t*-value is 2.096, which is higher than the benchmark of 1.96 (significant as *t* 2.096 > 1.96). The *p*-value of 0.037 is lower than the threshold value 0.05 (*p* 0.037 < 0.05). So, CPN and SDP have a significant relationship; thus, H[3] is acceptable.

Non-contract farming

H[4] Cellphone Networking (CPN) is significantly related to SDP under non-contract farming. (CPN→SDP)

The outcome reveals that the path coefficient between BTA and SDP is 0.074. The *t*-value is 0.265, lower than the threshold value of 1.96 (insignificant as t 0.265 < 1.96). Likewise, the p-value of 0.791 is higher than the threshold value of 0.05 (insignificant p 0.791 > 0.05). So, the finding is that H^4 is unacceptable, as there is an insignificant relationship between BTA and SDP.

H^5 Feeding Technology Adoption (FTA) has a significant relationship with SDP under non-contract farming. (FTA→SDP)

The finding shows that the path coefficient between FTA and SDP is 0.227. The t-value is 1.093, which is lower than the value of 1.96 (insignificant as t 1.093 < 1.96). Consecutively, the p-value of 0.275 is higher than the threshold value 0.05 (insignificant as p 0.275 > 0.05). Therefore, H^5 is not acceptable. There is an insignificant relationship between FTA and SDP.

H^6 Cellphone Networking (CPN) without contractual farming has a significant relationship with SDP.

It is revealed that the path coefficient between CPN and SDP is 0.412. The *t*-value is 2.402, which is higher than the value of 1.96 (significant as t 2.402 > 1.96). Similarly, the p-value of 0.017 is lower than the threshold value 0.05 (significant 0.017 < 0.05). Therefore, it is concluded that H^6 is acceptable, thus, a significant relationship between CPN and SDP. See Tables 6.1 and 6.2.

Table 6.1 Technology Adoption under Contract Farming

	Contract Farming					
	Hypotheses	**Original Sample (O)**	**Mean (M)**	**SD**	***t* Statistics**	***p* Values**
H^1	BTA significantly related to SDP under contract farming	0.438	0.1393	0.168	2.607	0.012
H^2	FTA significantly related to SDP under contract farming	0.438	0.39	0.204	2.144	0.033
H^3	CPN significantly related to SDP under contract farming	-0.35	-0.294	0.167	2.096	0.037

Table 6.2 Technology Adoption under Non-Contract Farming

	Non-contract Farming					
	Hypotheses	**Original Sample (O)**	**Mean (M)**	**SD**	***t* Statistics**	***p* Values**
H^4	BTA significantly related to SDP under non-contract farming	0.074	0.133	0.278	0.265	0.791
H^5	FTA significantly related to SDP under non-contract farming	0.227	0.151	0.207	1.093	0.275
H^6	CPN significantly related to SDP under non-contract farming	0.412	0.464	0.171	2.402	0.017

Note: t value threshold > 1.96
P value threshold < 0.05

Table 6.3 Descriptive Statistics

Demographic Information	Categories	Frequency	Valid %	Demographic Information	Categories	Frequency	Valid %
Types of Cows	Local	6	12	Types of Cows	Local	32	64
	Hybrid	44	88		Hybrid	17	34
	Both	-	-		Both	1	2
Breeding Type	**Friesian Cross**	**43**	**86**	Breeding Type	**Friesian Cross**	**10**	**20**
	Jersey Cross	2	4		Jersey Cross	10	20
	Indigenous Cattle	5	10		Indigenous Cattle	30	60
	Others	-	-		Others	-	-
Breeding Process	Natural	6	12	Breeding Process	Natural	10	20
	Artificial insemination	44	88		Artificial insemination	40	80
Feeding	Processed feed	30	60	Feeding	Processed feed	10	20
	Non-Processed	4	8		Non-Processed	35	70
	Both	16	32		Both	5	10
Cell Phone Use	Normal Cell Phone	13	26	Cell Phone Use	Normal Cell Phone	30	60
	Smart Phone	30	60		Smart Phone	16	32
	No Cell Phone	7	14		No Cell Phone	4	8
Milk Production per day per cow	20 litre and less	14	28	Milk Production per day per cow	20 litre and less	38	76
	21-40 litre	**21**	**42**		**21-40 litre**	**11**	**22**

The above findings are also congruent with the descriptive statistics. See Table 6.3.

Table 6.3 shows that 86% of contract farmers used Friesian Cross against 20% of non-contract farmers. Contract farmers had 88% hybrid cows, while non-contract farmers had 34%. The cow's daily milk output is 42 (contract) or 22 (non-contract) liters. Broth contract farmers (88%) and non-contract farmers (80%) employed Artificial Insemination (AI) for breeding. Contract farmers used AI conducted by a company's free veterinarian rather than self, a skilled co-farmer or ghost veterinarian. Thus, the output may vary. Contract farmers are guaranteed follow-up AI, while non-contact farmers are not. The service is free for the contract, and the cost is incurred for the non-contract.

Feeding patterns also varied between the two categories. 80% of contracts and just 20% of non-contracts utilized processed feeds, with 8% and 70% using non-processed food, respectively.

In cell phone use, 60% of contract and 32% of non-contract farmers had a smart cell phone, whereas 26% and 60% of contract and non-contract farmers had a regular phone during the study.

7. Discussion

Smallholder farmers produce 75-80% of Bangladesh's milk (Uddin et al., 2022). Yet, the supply is inadequate to fulfill the growing population's demand (nutrition, protein, meat) and industrial users (BBS, 2020). In Bangladesh, 85-90% of indigenous cattle and 10-15% of crossbreds generate subsistence dairy (Faruque et al., 1990; Habib et al., 2017). So, technology adoption can be crucial to address this growing need (Nleya & Ndlovu, 2021).

Although researchers have identified many factors contributing to sustainable dairy production, technology is still dominant in all respects—particularly in extension services, production process, output, and supply chain (Prajapati et al., 2021).

Adoption is challenging owing to farmers' subsistence-level socioeconomic conditions. They require help from stakeholders like local governments, NGOs, cooperatives, and industrial dairy processors. The private sector's contribution to technology adoption under contract farming is significant (Antor et al., 2020; Das et al., 2021; Haq & Raju, 2022; Islam et al., 2019; Quddus, 2013). A sizable body of research has been done in this respect, but most addressed individual factors for convenience.

This study assessed and compared the impact of technology adoption in breeding, feeding, and cell phone networking on contract and non-contract dairy farming with a private processor (Quddus, 2013).

7.1 Breeding

Sustainable dairy begins with breeding. Genetic techniques, such as crossbred, are the classical method of increasing dairy output. Genetics and biometry are used to improve farm animal productivity. It is crucial from conventional to organic animal production. Bangladesh's 80% indigenous cows and poor productivity make breeding essential. Government-funded community breeding efforts in Bangladesh are insufficient (Khan et al., 2009), so NGOs make sporadic attempts. In this respect, the private sector can play a vital role by importing high-yield breeds, preserving and inseminating (AI) them with vets, and tracking results to reduce risks using advanced technology. However, breeding for higher yields could lead to weaker, less fertile animals. Genetic modification has long-term benefits in the community (Haile et al., 2019; Röös et al., 2018). Farmers who are on their own and do not have these things may have unproductive results like miscarriages. The results of this study have strongly backed up this claim that BTA has a significant relationship with SDP under contractual farming with the private processor. Conversely, BTA has an insignificant relationship with SDP under non-contractual farming.

7.2 Feeding

Genetic and nutritional problems mainly cause the low productivity of dairy cattle production in Bangladesh. These animals may not show their genetic superiority unless food management is addressed. Feeding dairy cattle a high-quality diet in sufficient amounts is vital to enhance output (Skider et al., 2001). Quantitative and qualitative shortages of feed and fodder affect milking animals. Local animals provide 1.5 liters of milk per day, compared to 5-8 liters for cross-bred cows, and need higher food, mainly concentrates, which farmers cannot afford (Khan et al., 2009).

Feeds equate milk quantity and quality (Nleya & Ndlovu, 2021). Rice straw, natural grasses, and little or no concentrates are traditional dairy cattle feed. These feeds are seasonal, and changes affect pasture fodder quantity, quality, and limited availability in the dry season. Effective utilization of current feed resources (agricultural and agro-industrial leftovers and natural pastures) and supplementing low-quality natural pasture and crop waste diets are crucial to improving dairy animal nutrition. Poor nutrition promotes low output and reproduction, delayed growth, weight loss, sickness, and parasite susceptibility (Khan et al., 2009).

Many supplementing approaches may be utilized depending on the kind, availability, and cost of extra meals. For year-round feed, hay and silage should be conserved. It's necessary to examine the nutrient content of tree leaves and pods to enhance their use (Nleya & Ndlovu, 2021). The feeding habit of cattle also changes with the temperature rise (Legrand et al., 2009), so Holstein black cows and other dark-skinned breeds produce less milk as the temperature outside peaks (Anzures-Olvera et al., 2019). Feeding intake also varies in the evening, night, and early morning (Legrand et al., 2009).

So feeding management is a science that demands technological know-how (Khan et al., 2009). Smallholder farmers with little or no knowledge, insufficient training, and poor feeding management might affect dairy production. This study found that FTA has a significant relationship with SDP under a contract partnership compared to non-contract farmers, resulting in an insignificant relationship between FTA and SDP.

7.3 Cellphone Networking

Many studies have discovered the usefulness of mobile phones in agriculture (Kavitha et al., 2013; Mittal, 2012).

Cell Phones are widely used in agriculture, particularly in livestock and dairy. It is more necessary for remote farmers with difficulty finding information on extension services, production processes, and supply chains. Since dairy is a time-critical (perishable) and information-intensive commodity, it requires constant input and stakeholder communication (Mamun-ur-Rashid et al., 2019). However, information collection and gathering are costly and challenging (Milovanović, 2014).

Similarly, farmers in Bangladesh have trouble getting the information they need because of flaws in the agricultural extension system (Mamun-ur-Rashid & Qijie, 2016). Examples include information on veterinary care, sperm banks, training centers, grants, and other forms of aid. Due to a severe staff shortage (1:900–2000 farmers), the Department of Agricultural Extension cannot provide enough assistance to the agricultural community (Miah, 2015). The Upazila (Sub-district) Veterinary Hospitals (UVH) are the center of DLS' grass-roots efforts—one vet for 150,000 animals at a UVH. So, grass-roots service delivery is insufficient and rare (Uddin et al., 2022). Remote dairy producers need extension help to grow the industry. There is no evidence of public extension's market extension services, which are vital to the dairy industry. An alternate form of continuous service delivery to farmers is required (Uddin, 2015).

Uddin et al. (2016a) studied and proposed two service delivery models for smallholder dairy farmers. First, recruit more state extension staff. Second, promote affordable demand-driven farmers' organization-based extension (Uddin et al., 2016). It is called the Community-Based Dairy Veterinary Foundation (CDVF). Although it is helpful for farmers, the foundation lacks a reliable monitoring mechanism for its core stakeholders' livelihood. However, Other livelihood studies demonstrate CDVF has decreased smallholder dairy producers' vulnerability (Uddin et al., 2017).

Contract farming is still widely accepted by dairy farmers. Farmers produce milk, and the private dairy processor requires it for processing. It's a demand-supply swap. Both sides use mobile phones for extension services and smooth operations. Due to weak infrastructure and resource constraints, mobile phones are essential for farmer-processor collaboration and interaction.

Bangladesh's cellphone industry has exploded since 1993. 158.44 million mobile subscribers represented 97.02% of the 163.288 million population in March 2019 (BTRC, 2019). Mobile network coverage topped 99% of residents (Milesi-Ferretti, 2019). Farmers must know the information they need, the sources they utilize, and the phones' utility to use them effectively (Mamun-ur-Rashid et al., 2019). The advantages of cell phones in rural dairy farming include extension services (veterinary, health check, vaccines, feeds, emergency calls, price check, complaints), banking (check account, payment received, bill payment, transfer), weather (rain, temperature, storm), production (process, hygiene and sanitation check, receive tips from the company staffs or peers), market (supply chain, Better market connectivity and distribution connections; better market and value chain entry; fraud reduction; current market prices) training (Greater skills and knowledge, a good attitude, on the work tips, schedule, skills, positive attitude), development, and social networking (interpersonal relationship, group efforts, healthy neighborhood, social security, mobility, and empowerment, entertainment (Aker, 2011; Mamun-ur-Rashid et al., 2019; Mittal, 2012; Singh & Issac, 2018). However, the intensity of cell phone use depends on demographic factors. Small-scale poultry farmers in Ghana are more likely to use a mobile phone if they are older, have more education, have been in the business longer, and have more land (Folitse et al., 2019).

The most notable results of this research were a strong association between CPN and SDP in contract and non-contract farming. It suggests that contract farmers continually communicate with PDL specialists about dairy recommendations, emergency calls, pricing, immunization schedule, farm visit, training on mobile apps, and any concerns. By putting their apps on all the farmers' phones, the dairy company made it easier for them to use their phones. A recent study focuses on the user acceptability of new technologies. (Kabbiri et al., 2018; Park & Angel, 2013). The study also discovered that the Technology Acceptance Model (TAM) is adaptable to various variables (Luarn & Lin, 2005).

Research findings on the use of cell phones by non-contract farmers are mixed. They indicate that cell phones are the least preferred due to a lack of knowledge and skills. Contrarily, some researchers think that non-contract dairy farmers use the mobile phone for diverse purposes, including updated feed prices, dairy, on-call veterinarians or technologists in the market, and intermediaries. Researchers referred to this as access to information for those who had never owned a landline telephone (Aker, 2011). It is further claimed that using mobile phones helps speed up the transition to sustainable agriculture in Africa (Batchelor et al., 2014). The research proposed a robust, coordinated effort by local stakeholders, the commercial sector, expert institutes, and governments (Batchelor et al., 2014). This stress the benefits of contract farmers having partnerships.

According to studies, a tech-based marketing channel may help Bangladeshi farmers. The research recommends a mobile-based channel—'Smart GOALA'—for connecting peri-urban farmers with urban buyers, assuring better and fairer pricing. This is critical for non-contract milk sellers. However, the use of technology also depends on the user's behavioral intention (Wu & Wang, 2005), which is congruent with the perceived use and utility of that technology (Kabbiri et al., 2018).

7.4 Summary of Hypotheses

Table 6.1 provides an overview of the hypotheses. It was revealed that contract farming, as opposed to non-contract farming, is a preferred alternative for technology adoption and sustainable dairy production.

Table 7.1 Summary of Hypotheses

Hypotheses	Variables	Category	Results
H^1	BTA → SDP	Contract Farming	Supported
H^2	FTA → SDP		Supported
H^3	CPN → SDP		Supported
H^4	BTA → SDP	Non-contract Farming	**Not Supported**
H^5	FTA → SDP		**Not Supported**
H^6	CPN → SDP		Supported

8. Conclusion

The global population is experiencing rapid growth. The significant change in worldwide dietary patterns increased the demand for milk, nutrition, protein, and vitamins. This increased milk output to suit industrial and consumer requirements. Smallholder dairy farmers generate 70–80% of Bangladesh's milk. They are impoverished, socially disadvantaged, and ecologically uninformed. Their farming method is rudimentary for milk production. Thus, they require help from stakeholders (government, NGOs, and cooperatives). A private dairy company is a vital shareholder. They require milk to make dairy products. Contract farming involves a private corporation providing extension services and other support to dairy farmers, who then give milk to the enterprise. This protects the company's raw milk supply chain and a 100% buy-back policy for the farmer.

Technology adoption is crucial for smallholder sustainable dairy production. Technology is an essential element in meeting the extended demand. It costs money, and impoverished farmers need support from stakeholders. The private dairy processor can support these farmers with technology adoptions. This study examined the relationship between technology adoption (breeding, feeding, and cell phone networking) and sustainable dairy production. The findings of this study support contract farming as opposed to non-contract farming. It also benefits the dairy industry, academia, researchers, and policymakers.

9. Limitations of the study

This study had time and fund constraints. It considers only two primary districts. Future research should include more districts for study. A mixed method could have been a better approach, but this study only considered a quantitative method.

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Contribution of co-authors

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Ethical Considerations

The authors have reported no conflicts of interest regarding this paper's study, writing, and/or publication.

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