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Islands of Milk Insecurity in World's Leading Milk Producer: A Case of Andaman and Nicobar Islands, India

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Abstract: India, with the world's largest cattle population, is a leading producer of milk, and claims to be self-sufficient for dairy production. However, such an important component for nutritional security has been reported to be adulterated by 68% by the national food safety agency. This study challenges the basic claim of self-sufficiency in terms of milk production and food security for milk and milk products. A novel model for studying milk safety is presented, which evaluates the prevailing conditions in the Andaman and Nicobar Islands (A&N), India. There are no comprehensive data nor studies available for this region. The assessment of the pillars of food security found that with the present population load, there is an annual deficit of 25673.7 MT of fluid milk in the A&N Islands. The study found that the average herd size is 1.9, with about 26.9% of the animals rearing desi (non-descriptive) cattle, characterized by low production levels of 3.95 L/day and with gene frequency of 16.48% for the A1 allele. None of the milk samples were found to be positive for antibiotic (tetracycline and aminoglycoside) residues. However, 4% of the milk samples were found to be positive for the aflatoxin residues above the permitted MRL. The KAP study shows that awareness regarding clean milk production, antimicrobial residues, withdrawal timings, aflatoxins, etc. is poor/highly limited among the farmers of the region. The output may act as a referral study and a template for future studies for the assessment of product-specific food security. Our findings highlight the limitations of the present approach and the need for additional data, using a wider range of research techniques for assessing dairy. Whilst not definitive, it aims to highlight those factors which are considered crucial to an understanding of contemporary milk safety controls.

Keywords: milk insecurity; food safety; food security; health hazards

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1. Introduction

India is the leading producer of milk in the world. It produced 187.6 million tons of milk in the year 2018–2019, accounting for 21% of the world's milk production, with a national per capita availability of 394 g/day [1]. The Indian government agencies claim to have achieved self-sufficiency in the dairy sector [2,3]. However, the national Food Safety and Standards Authority of India, in its reports from 2012 and 2018, revealed the existence of health hazards in milk and milk products beyond the permitted safe values [4–6]. In a country with a population of 1.38 billion, including children, pregnant women, older people, etc., consuming milk as a healthy beverage, these reports often lead to apprehension and raise concerns about nature's complete food—milk. Thus, considering the issues of milk safety as reported by multiple agencies, the claim of self-sufficiency needs to be revisited to ascertain the basic reasons leading to such a claim.

The overall estimation of self-sufficiency on the basis of total milk production and per capita milk availability, the two widely used indices in India, may not be highlighting the true picture from a consumer safety perspective, considering the public health significance of such a widely important food commodity. Thus, a far more comprehensive indicator, such as Food Security, is required to assess the self-sufficiency of such an important food commodity. The potential of milk and milk products is not only limited to the nutritional security of the consumer, but dairy development also plays a significant role in rural development. The study was conducted in the Andaman and Nicobar (A&N) Islands, India, which is lagging behind the rest of the country, as the per capita availability of milk in Andaman and Nicobar Islands is only 96 g/day compared to the national average, which was 375 g/day in 2018–2019 [7]. The total milk production in the A&N Islands was 18,000 metric tons in 2018–2019, with a milch animal population of 17,000 cattle. Thus, this region is characterized by a low per capita production status of 2.9 Kg/day [8].

For the holistic development of the dairy sector, a comprehensive dairy development plan is required, which may require detailed assessment of the present prevailing conditions. The success of any plan depends significantly on the accuracy of the corrective measures being put in place. Miscalculations can lead to negative consequences, ranging from introduction of new diseases to economic losses to farmers, loss of biodiversity, etc. This study evaluates the existing scenario in the dairy sector, with a focus on fluid milk safety, as well as the factors with impact on the quality of milk reaching consumers on the islands. The study accesses the food security of the study population for fluid milk.

2. Materials and Methods

2.1. Location

The Andaman and Nicobar Islands are the largest archipelago in the Bay of Bengal, consisting of 576 islands situated between 6°45′ N to 13°41′ N latitude and 92°12′ E to 93°57′ E longitude, as depicted in Figure 1. This large archipelago is separated from mainland India by 1200 km; the nearest landmass in the north is Myanmar, roughly 280 Km north of Landfall Island. The average maximum temperature is 30.1 °C, and the minimum temperature is 23 °C. The relative humidity is in the range of 82–94%. The annual rainfall is more than 3100 mm, spread over 8 months, and remaining 4 months of the year constitute the dry season [9].

Figure 1. Map of Andaman and Nicobar Islands, India [10].

2.2. Assessment of Dairy on Four Pillars of Food Secruity

The level of food security for any region results from the combined action of many factors [11]; thus, any single perspective cannot accurately reflect it [12]. To evaluate the prevailing conditions of the dairy sector in the A&N Islands, the assessment is based on the four pillars of Food Security defined by FAO, i.e., the availability, accessibility, utilization, and stability of the supply chain, as well as total milk production, per capita milk availability, and prevailing prices as the key indicators to characterize the situation. The local demand for fluid milk is calculated based on the per capita dietary recommendations of the National Institute of Nutrition, India.

2.3. Assessment of Dairy for Food Safety

The review of the quality control mechanisms for dairy in the A&N Islands was conducted. A retrospective audit to collect primary data and test reports from the State Food Safety Laboratory, Port Blair on food safety analysis of milk samples a was conducted. Fifty-six reports of milk samples processed by the State Food Safety Laboratory, Port Blair, for the period between October 2018 and September 2019 were collected and analyzed.

2.4. Assessment of Blood and Milk Samples for Identified Food Safety Hazards

Although many contaminants can be potential milk safety hazards, the present study focused on the unstudied and underreported aspects of the present dairy supply chain, such as the prevalence of the A1 allele in the cattle population, and aflatoxin and antibiotic residues in liquid milk.

2.4.1. Blood Samples

For evaluating the type of beta-casein in the milk, genotyping of the cattle was performed and then correlated with the existing breeding policy of the region. Blood samples from 387 cattle were collected from different parts of the A&N Islands. A blood sample of approximately 5 mL was drawn from each animal by jugular venipuncture into a vacutainer containing EDTA. Samples were transported to the laboratory, maintaining cold chain. The genomic DNA was extracted from the blood samples by enzymatic digestion using proteinase K followed by the routine phenol–chloroform extraction method [13]. Genotyping was conducted by polymerase chain reaction-restriction fragment length polymorphism (PCR-RFLP), as described by Lien et al. [14]. A 251-bp fragment of exon 7 of the β-casein gene was amplified using primers, as reported by Lien et al. [14]. PCR was performed in a thermal cycler (A37029 Mini Amp plus, Applied Biosystems, Waltham, MA, USA) in a reaction volume of 25 µL, containing 50 ng of genomic DNA, 5 pmol of each primer, 200 µM dNTPs, 1.5 mM $MgCl_2$, and 1 U Taq DNA polymerase. The thermal cycling condition was as follows: 95 °C for 5 min, followed by 30 cycles at 94 °C for 30 s, 63 °C for 40 s, and 72 °C for 20 s, with a final extension at 72 °C for 3 min. The purified PCR products of each sample were digested with 5 U Taq I restriction enzyme at 65 °C for 3 h. The digested products were resolved on 3.5% agarose gel (Sigma Chem. Co., St. Louis, MO, USA). After completion of electrophoresis, the gel was examined under a UV transilluminator/Gel documentation system (BioRad, Molecular Imager, GelDoc TM XR, Imaging System, Hercules, CA, USA) and genotypes were recorded according to fragment size (Figure S1). The genotype frequencies at the A1/A2 locus were calculated by the direct counting method i.e., by counting the number of bands appearing in the gels. The genotype and gene/allele frequencies were calculated by using the following formulae:

$$Genotype\ frequency = \frac{No.\ of\ animals\ with\ particular\ genotype}{Total\ number\ of\ animals}$$

$$Gene\ frequency = \frac{(2 \times no.\ of\ homozygote) + (no.\ of\ heterozygote)}{2 \times Total\ number\ of\ animals}$$

2.4.2. Milk Samples

The evaluation and screening of the milk samples by rapid action test kits, using a lateral flow technique, was performed for the detection of aflatoxin M1 and antibiotic residues at ICAR-Central Island Agricultural Research Institute, Port Blair, using a Charm ROSA test [15] (Figure 2). This is one of the easiest methods for rapid detection of contaminants in milk [16]. The screening results can be obtained in a short time [17], and the test is both highly sensitive and able to detect even low concentrations of residues [18,19]. The lateral flow-based test has a high sensitivity and specificity (15). A semiquantitative lateral flow-based rapid one step assay (ROSA), produced by Charm Sciences, was tested in an interlaboratory study and found to be efficient tool for screening samples; it revealed only 4.8% false negative results [17,20]. A 300 μL milk sample was taken in a vial using a dropper supplied with the kit. Afterwards, the vial with the sample was placed in the CHARM Dip test incubator. The test strip was added to the vial and incubated for 8–10 min. After incubation, the strip was compared to the standard comparison sheet supplied with the kit, and visually read. The selection of antibiotics for the present study was based on a review of the commonly used drugs for treatment of the dairy animals in the islands. It was found that tetracycline and sulfonamides were the most commonly used antibiotics, and thus, these were screened in the milk samples.

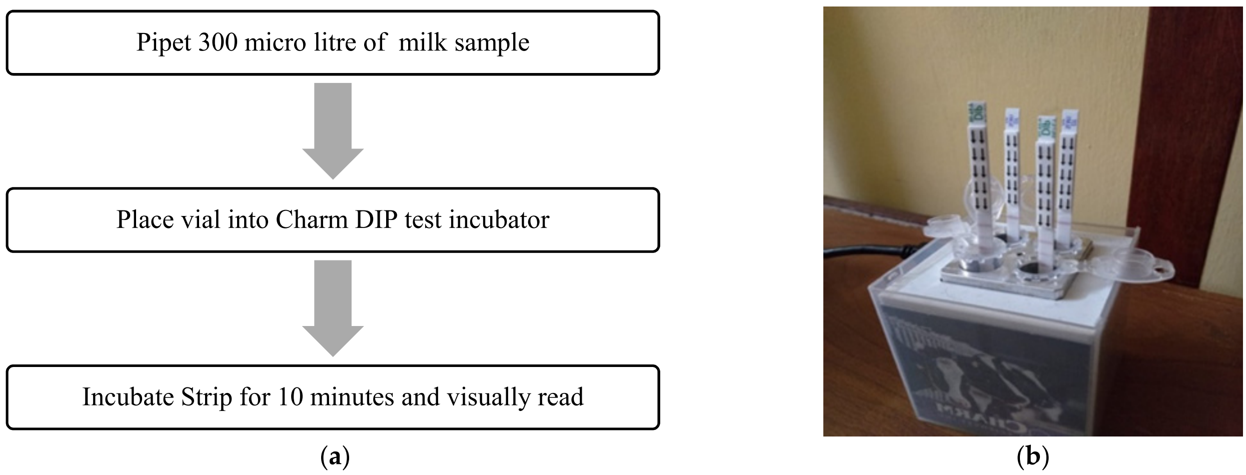


Figure 2. (**a**) Test procedure for processing milk samples by Charm ROSA Dip Kit; (**b**) actual picture of using Charm ROSA Dip test kit.

As per the general principle in lateral flow tests, the sample is placed onto a pad, where the chemical residues are bound to antibody gold particles. These antibody gold particles and second (on the pad mobilized) antibody gold particles migrate to the test zone and the control zone, which contain a membrane. The mycotoxin antibody gold particle complex binds in the test zone to an AF protein conjugate, while the second antibody gold complex binds in the control zone that allows for the formation of a colored line. If the AFs concentration is equal to or greater than the defined cut-off level, a colored line in the test zone will be visible. In the control zone, a line always appears (in absence of AFs) after binding of the gold particle to the second antibody.

2.5. Assessment of Milk Safety Practices Followeed by the Dairy Farmers

Cross-sectional study design is a type of observational study design used for population-based surveys; it is fast and inexpensive [21]. The cross-sectional study design-based Knowledge Attitude and Practices (KAP) surveys help to point out the inadequacies of the existing system and to provide the corrective feedback to overcome the shortcomings. In the current study, evaluation of farmers was undertaken through a cross-sectional study to assess the knowledge, attitude, and practices of the farmers towards the cattle breeds, the potential of zoonosis, and milk hygiene practices. The survey was conducted on a total of 300 farmers in all three districts of the Andaman and Nicobar Islands at the rate of 100 farmers/district. Because of the language barrier, the survey was not conducted in the English language, but in the local languages, i.e., Hindi, Bengali, Punjabi, etc., and then the results of the questionnaire were recorded in English.

3. Results

3.1. Assessment of Prevailing Dairy Status against the Pillars of Food Security

3.1.1. Availability

The Andaman and Nicobar Islands have a human population of 380,581 [22], and being a tourist destination, the place also experiences an influx of tourists. The local milk production in the Andaman and Nicobar Islands was 18,000 metric tons in the years 2018–19 [8]. A food product's availability is dependent on two factors, i.e., local production and imports from outside, to meet the demand of population. Considering the National Institute of Nutrition's (NIN) per capita recommendation of 300 g/day, the annual milk requirement of the island amounts to 41,673.7 metric tons [23]. The detailed district-wise distribution is calculated in Table 1. Thus, the area has an annual deficit of 23,673.6 metric tons based on the estimates of local production. The detailed district-wise distribution of salient features of the dairy sector is shown in Table 1.

Table 1. Data relevant to the dairy sector in the A&N Islands.

District	Cattle Population		Human Population	Annual Milk Requirement (MT) *	Milk Processing Plant	Food Safety Laboratory
	Cow	Buffalo				
North and Middle Andaman	25,049	6849	238,142	26,076.6	Nil	Nil
South Andaman	17,927	985	105,597	11,562.9	01	01 State Food Laboratory 01 Forensic Science Laboratory
Nicobar	2649	29	36,842	4034.2	Nil	Nil
Total	45,625	7863	380,581	41,673.7	01	02

* Assessment based on the per capita requirement of 300 g/day of the National Dietary Guidelines, Government of India.

The produced milk passes through different supply chains before it reaches the consumers. The local milk produced in the islands is either collected by the government agency Andaman and Nicobar Islands Integrated Development Corporation Limited (ANIIDCO), or passes through the unorganized supply chain to reach the consumers. ANIIDCO is the only organized supply chain processor in the islands, and it procures an average of only 70,000 L milk per month [24], which is low considering the processing capacity of 8000 L per day through their centers linked to farmers. This quantity accounts for less than 28.8% of its processing capacity and only 4.7% of milk being produced in the islands. Due to the scarcity of milk in the islands, various traders are importing milk and milk products from the mainland. The official estimates of the amount of milk imported into the islands is not recorded, and, thus, is unavailable.

3.1.2. Accessibility

Considering the well-developed network of marine and terrestrial transport systems, the physical accessibility of shelf-stable products is not an issue. However, the products prepared by ANIIDCO are pasteurized in nature, require continuous refrigeration, and are present in South Andaman district only. Thus, there is market for ultra-high-temperature-treated (UHT) products to be imported into the islands, owing to their extended shelf life and minimum refrigeration requirements. However, they also come at a premium price as compared to pouch-packed milk.

Apart from geographical access, economic access also impacts the accessibility of a food product. Taking reference from the prices of milk products in other cities of the country, it can be seen that the milk prices are approximately 40–60% costlier in Port Blair, the capital of Andaman and Nicobar Islands (Table 2). The inflated cost of milk products in the islands may reduce the economic access of the population to these products. Due to the costs of importing, distribution, etc., the price of milk and milk products is very high in the region, and only UHT milk products are brought by traders due to their extended shelf life. This may result in reduced accessibility of milk and milk products for the consumer population.

Table 2. Economic comparison of milk prices at Port Blair with other metro cities.

Name of Product [1]	Specification	New Delhi (Amul)	Mumbai (Gokul)	Kolkata (Mother Dairy)	Chennai (Aavin)	Port Blair (ANIIDCO)
Toned Milk	3% fat and 8.5% SNF	44	48	44	40	56
Cow Milk	4% fat and 8.5% SNF	46	49	46	-	74

[1] All product types selected for comparison are pasteurized during pouch packing. The prices are collected by direct inquiries.

3.1.3. Utilization

This aspect deals with the ability of the consumer to appropriately utilize the product. Considering the traditional knowledge of the Indian system for the consumption of milk and milk products, its consumption is no longer considered a practical issue for this region. The utilization of milk can be compromised in a specialized group of individuals, such as patients impairing its physiological utility in consumers, but the study of this aspect is beyond the scope of the present study.

3.1.4. Stability

This dimension deals with the ability of the nation/community/person to be able to withstand shocks to the food chain system, whether caused by natural disasters (climate, earthquakes) or those that are man-made (wars, economic crises). The societal impact of these disasters is extremely catastrophic, as seen in the Tsunami of 2004 in the A&N Islands. These islands are vulnerable to tsunamis generated from earthquakes originating from different sources that exist along the Sumatra Subduction Zone (SUSZ), Andaman Subduction Zone (ANSZ), and Arakan Subduction Zone (ARSZ) [25]. Considering the geographical isolation of A&N Islands and the shortage of local milk production, the population may be insecure in the future due to sudden disruptions by the aforementioned disasters. The recent example of the COVID-19 pandemic is a lesson for all governments globally to develop sustainable local food chains to ensure food security for the population, at all places and at all times.

3.2. Food Safety Systems in Place

The objective of milk security is incomplete without addressing the milk safety issues. The A&N administration has only one laboratory in the islands, namely the State Food Laboratory, which can process milk and milk products. However, it is no longer designated as the State Food Laboratory [26,27]. The State Forensic Laboratory in Port Blair does not process the market samples of milk, but analyzes them in case of medicolegal cases. The results of the milk samples processed by the State Food Safety Laboratory, A&N Administration, are not available on their official website, nor are they reported in any scientific/academic publications. Therefore, a retrospective audit was conducted to collect primary data and test reports on food safety analysis of milk samples. The available fifty-six reports of milk samples processed by the State Food Safety Laboratory, Port Blair, for the period between October 2018 and September 2019, were provided by laboratory officials. They were collected and analyzed in order to ascertain the type of tests conducted and the results achieved, and this analysis is depicted in Table 3. The key salient observations based on the analysis of these reports are as follows:

i. The local screening is limited to the basic adulteration tests. The samples were only processed for their basic quality parameters, namely urea, detergents, soda, starch, fat, SNF, and water. The lack of quantitative hazards analysis depicted in the reports correlates with the observation of the FSSAI that the state food laboratories lack sophisticated analytical equipment and microbiological laboratory for the testing of various safety parameters, such as heavy metals, pesticide residues, antibiotic and drug residues, and naturally occurring toxic substances, as well as microbiological parameters [28].
ii. Even with basic analysis, 48.2% of the milk fails to meet the requisite quality parameters during the review period. Similar results were reported for the period of 2017–2018, in which 57.8% of the milk samples in the A&N Islands were found to be adulterated and misbranded [29]. However, during the national survey on milk quality in 2018, which also collected 14 samples for testing from the region, none were found to be substandard [29]. Thus, a significant difference exists regarding the results of milk samples processed in the national survey and the reports of the local food safety laboratory.
iii. None of the milk samples were found to be positive for adulterants, namely urea, detergents, soda, and starch. The leading cause of the samples failing the quality tests was adulteration with water (35.7%), followed by low fat level (28.6%).
iv. The sample collection and processing is highly limited to the area of South Andaman, and not to the other districts. In addition, considering that over 99% of milk is handled by the unorganized sector, the chances of quality compromise may be high and, hence, require regular monitoring and screening.

Table 3. Retrospective audit of tests conducted on milk samples by the State Food Safety Laboratory, Port Blair, between October 2018 and September 2019.

S. No.	Report No.	Urea	Detergent	Soda	Starch	Fat	SNF *	Water	Result
1	MFTL/2019/377	N *	N	N	N	3.70%	6.34%	Positive	Fail
2	MFTL/2019/382	N	N	N	N	3.00%	9.00%	Negative	Fail
3	MFTL/2019/385	N	N	N	N	3.80%	8.50%	Negative	Pass
4	MFTL/2019/387	N	N	N	N	3.70%	8.60%	Negative	Pass
5	MFTL/2019/388	N	N	N	N	3.80%	8.80%	Negative	Pass
6	MFTL/2019/164	N	N	N	N	3.30%	-	Negative	Fail
7	MFTL/2019/172	N	N	N	N	4.50%	8.60%	Negative	Pass
8	MFTL/2019/181	N	N	N	N	0.60%	7.91%	Positive	Fail
9	MFTL/2019/182	N	N	N	N	0.61%	7.75%	Positive	Fail
10	MFTL/2019/183	N	N	N	N	0.63%	7.74%	Positive	Fail
11	MFTL/2019/184	N	N	N	N	0.60%	7.87%	Positive	Fail
12	MFTL/2019/185	N	N	N	N	0.58%	7.78%	Positive	Fail
13	MFTL/2019/143	N	N	N	N	2.65%	6.61%	Positive	Fail
14	MFTL/2019/138	N	N	N	N	4.50%	8.60%	Positive	Fail
15	MFTL/2019/136	N	N	N	N	3.06%	7.04%	23.90%	Fail
16	MFTL/2019/135	N	N	N	N	2.87%	6.66%	24.40%	Fail
17	MFTL/2019/128	N	N	N	N	3.16%	7.85%	Negative	Fail
18	MFTL/2019/126	N	N	N	N	4.50%	8.60%	Negative	Pass
19	MFTL/2019/56	N	N	N	N	3.80%	9.40%	Negative	Pass
20	MFTL/2019/55	N	N	N	N	4.50%	8.90%	Negative	Pass
21	MFTL/2019/54	N	N	N	N	4.50%	8.50%	Negative	Pass
22	MFTL/2019/53	N	N	N	N	3.60%	10.50%	Negative	Pass
23	MFTL/2018/27	N	N	N	N	3.70%	8.60%	Negative	Pass
24	MFTL/2018/26	N	N	N	N	3.60%	8.60%	Negative	Pass
25	MFTL/2018/25	N	N	N	N	4.00%	9.00%	Negative	Pass

Table 3. *Cont.*

S. No.	Report No.	Urea	Detergent	Soda	Starch	Fat	SNF *	Water	Result
26	MFTL/2018/24	N	N	N	N	5.50%	8.50%	Negative	Pass
27	MFTL/2018/23	N	N	N	N	4.20%	9.50%	Negative	Pass
28	MFTL/2018/22	N	N	N	N	3.50%	9.00%	Negative	Pass
29	MFTL/2018/21	N	N	N	N	3.20%	6.20%	32.00%	Fail
30	MFTL/2018/20	N	N	N	N	2.70%	6.20%	33.00%	Fail
31	MFTL/2018/19	N	N	N	N	3.10%	6.80%	25.80%	Fail
32	MFTL/2018/18	N	N	N	N	3.10%	6.90%	25.00%	Fail
33	MFTL/2018/17	N	N	N	N	4.80%	8.90%	Negative	Pass
34	MFTL/2018/16	N	N	N	N	4.20%	8.90%	Negative	Pass
35	MFTL/2018/15	N	N	N	N	3.50%	8.60%	Negative	Pass
36	MFTL/2018/14	N	N	N	N	3.50%	8.60%	Negative	Pass
37	MFTL/2018/13	N	N	N	N	2.50%	6.50%	Positive	Fail
38	MFTL/2018/12	N	N	N	N	5.10%	9.40%	Negative	Pass
39	MFTL/2018/11	N	N	N	N	3.60%	8.50%	Negative	Pass
40	MFTL/2018/10	N	N	N	N	3.60%	8.70%	Negative	Pass
41	MFTL/2018/09	N	N	N	N	3.20%	5.80%	39.00%	Fail
42	MFTL/2018/08	N	N	N	N	2.10%	5.20%	44.44%	Fail
43	MFTL/2018/07	N	N	N	N	3.80%	8.50%	Negative	Pass
44	MFTL/2018/06	N	N	N	N	3.10%	5.56%	41.00%	Fail
45	MFTL/2018/05	N	N	N	N	2.60%	6.50%	29.10%	Fail
46	MFTL/2018/04	N	N	N	N	3.70%	6.90%	36.70%	Fail
47	MFTL/2018/03	N	N	N	N	5.50%	9.00%	Negative	Pass
48	MFTL/2018/02	N	N	N	N	3.12%	5.08%	Negative	Fail
49	MFTL/2018/01	N	N	N	N	2.91%	7.03%	Negative	Fail
50	INF-07/19	N	N	N	N	3.60%	8.80%	Negative	Pass
51	SF/2019/25	N	N	N	N	2.90%	7.80%	11.40%	Fail
52	SF/2019/25	N	N	N	N	3.10%	8.50%	Negative	Fail
53	INF-14/191	N	N	N	N	3.50%	8.40%	Negative	Pass
54	INF-13/191	N	N	N	N	3.80%	7.60%	Negative	Pass
55	INF-12/191	N	N	N	N	3.60%	9.40%	Negative	Pass
56	INF-11/191	N	N	N	N	3.70%	8.50%	Negative	Pass

* N and SNF stand for negative/not found and solid not fat, respectively.

3.3. Laboratory Analysis

3.3.1. Beta-Casein (A1 vs. A2 Allele)

The cattle population of the A&N islands represents mixed inheritance from different breeds which were brought onto the islands and the semen used for the artificial insemination program. The detailed genotypes, along with the phenotypic characteristics, in the examined population are presented in Table 4. The obtained A1 and A2 gene frequencies in the samples from the field population were 16.48 and 83.52, respectively. The genotypic A2A2 frequency in the cross-bred, native, and total samples of field animals were 53.81, 92, and 67.04, respectively. No animals were found with the homozygous A1A1 genotype. The detailed district-wise genotypes and allele frequencies of β-casein in the sample population of the Andaman and Nicobar Islands of India are presented in Table 4.

Table 4. The claculated genotype and gene frequency of β-casein in the sample population of the Andaman and Nicobar Islands of India.

Area	Type	Genotype			Genotypic Frequency		Gene Frequency	
		A1A1	A1A2	A2A2	A1A2	A2A2	A1	A2
North and Middle Andaman District								
Rangat	Total	0	7	37	15.91	84.09	7.96	92.05
	Native	0	2	33	5.71	94.29	2.86	97.14
	Cross-bred	0	5	4	55.56	44.44	27.78	72.22
Mayabunder	Total	0	8	29	21.62	78.38	10.81	89.19
	Native	0	4	26	13.33	86.67	6.67	93.33
	Cross-bred	0	4	3	57.14	42.86	28.57	71.43
Diglipur	Total	0	9	34	18	82.00	9.00	91.00
	Native	0	1	27	3.57	96.43	1.79	98.21
	Cross-bred	0	8	7	53.33	46.67	26.67	73.33
Subtotal		0	24	107	18.32	81.68	9.16	90.84
South Andaman District								
Manglutang	Total	0	39	67	36.79	63.21	18.40	81.61
	Native	0	2	17	10.53	89.47	5.26	94.74
	Cross-bred	0	37	50	42.53	57.47	21.26	78.74
Havelock	Total	0	10	9	52.63	47.37	26.32	73.69
	Native	0	0	0	0	0.00	0.00	0.00
	Cross-bred	0	10	9	52.63	47.37	26.32	73.68
Subtotal		0	49	76	39.2	60.80	19.60	80.40
Nicobar District								
Car Nicobar	Total	0	9	8	52.94	47.06	26.5	73.53
	Native	0	0	0	0	0	0	0
	Cross-bred	0	9	8	52.94	47.06	26.5	73.53
Campbell Bay	Total	0	47	48	49.47	50.53	24.7	75.27
	Native	0	1	12	7.69	92.31	3.8	96.15
	Cross-bred	0	36	46	43.9	56.10	22.0	78.05
Subtotal		0	56	65	46.28	53.72	23.1	76.86

3.3.2. Screening of Milk Samples for Aflatoxin and Antibiotic Residues

As per the milk survey report of 2018, conducted by FSSAI, the antibiotic and aflatoxin residues are contributory factors, accounting for 70% of the total unsafe samples [29]. However, in the same survey, all the samples from the A&N Islands were found to be negative for both. As per the regular practice of the Food Safety Laboratory, Port Blair milk samples were only processed for common adulterants. In the current study, 300 milk samples were screened for antibiotic and aflatoxin residues using the LFT based Charm ROSA kits.

Antibiotic Residues in Milk Samples

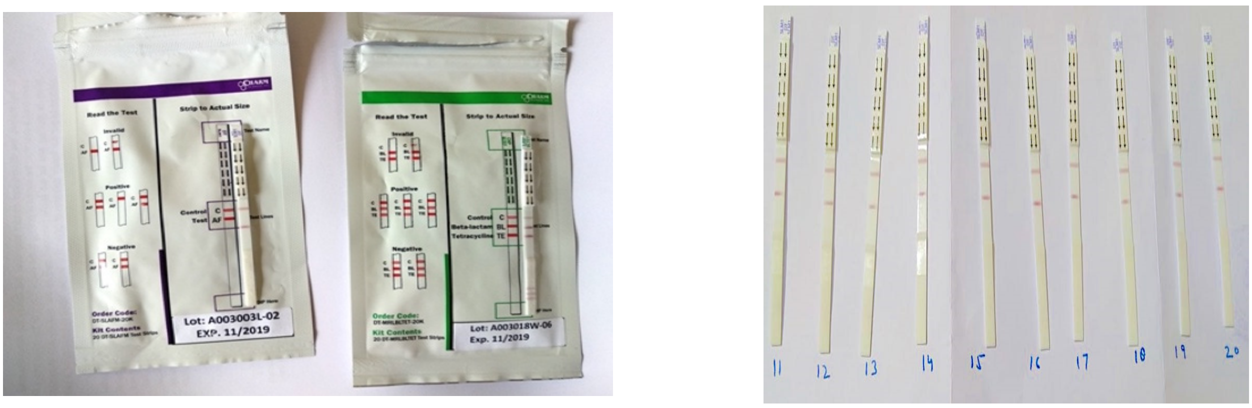
In the present study, none of the 300 milk samples tested positive for tetracycline or aminoglycoside antibiotics. Similar results were reported by the FSSAI survey conducted in 2018–2019 [29]. It is reported to be the only study conducted in the region by the government agency, with a sample size of only 14.

In another study in Thrissur, Kerala, out of 165 milk samples screened by MIA, it was found that 14 samples produced clear zones of inhibition and were considered positive for antibiotic residues. The occurrence of tetracycline and ß-lactam residues in milk samples using CHARM kits was found to be 1.82% and 2.42% of samples, respectively [30]. In another study in Thrissur, Kerala, the rates of incidence for residue in milk were 12% and 2% for beta lactam and tetracycline antibiotics, respectively [31]. Another study reported that 1.86% of the samples exceeded the maximum residue limits for oxytetracycline residues in milk, as specified by the Codex Alimentarius Commission/Food Safety and Standards Authority of India (FSSAI) in Kerala [32]. Another study from northern India showed the presence of residues in 11.7% of samples [33]. Another study in Punjab reported that out of milk samples from 492 dairy farms, 16% were found to be positive for antibiotic residues, with 4% exceeding the maximum residue limits [34]. In a recent study from Assam and Haryana, 40 samples out of a total of 491, or 8.14%, tested positive for antibiotic residues when screened with a strip-based assay [35].

As the tested samples in the present study have all been found to be negative in terms of these antibiotic residues, one of the most plausible reasons could be good farming practices, followed by farmers' judicious use of antibiotics and proper execution of the withdrawal periods. This may also have resulted from the dilution of the contaminated milk with good-quality milk as a part of regular practice of pooling milk, resulting in the lowering of concentrations below the detection range of the kits. The fact that most of the farmers have small holdings and operate within very small margins of profits, coupled with lack of availability of antibiotics in the open market, may have reduced the non-prescribed antibiotic consumption and, thus, led to a lower level of residues in milk samples. As antibiotic residues are potential health hazards and are prevalent in other parts of India, regular screening of the milk samples is recommended to ensure the safety of the consumers in the islands. Presently, this is not a part of tests conducted by the State Food Safety Laboratory, Port Blair.

Aflatoxin Residues in Milk Samples

The warm and humid climatic conditions prevailing in the A&N islands are ideal for fungal growth and, thus, pose a high risk of aflatoxicosis. This may indicate a health risk to consumers. The samples (100 per district) were collected from the three districts of A&N islands, processed, and read as depicted in Figure 3. Out of total 300 milk samples, 4% were found to be positive, above the permissible limit of 0.5 μg/L, for AFM1, with the highest district-wise distribution in South Andaman, followed by N&M Andaman, at a rate of 8% and 4%, respectively. None of the samples from the Nicobar district were found to be positive for these residues.



(**a**) (**b**)

Figure 3. (**a**) Manual reading of Charm ROSA Dip Kit strip; (**b**) actual picture of Charm ROSA Dip test kit strips used in the test.

In comparison to the prevalence of aflatoxin residues in 4% of milk samples in the present study, a cross-sectional study from Punjab, India revealed that 56.2 and 13.4% of the milk samples exceeded the maximum levels of the European Union, i.e., 0.05 μg/L, and the Food Safety and Standards Authority of India (FSSAI), i.e., 0.5 μg/L, respectively, for AFM1 in milk [36]. In another study from Punjab, 51% of samples were found to be positive for AFM1, while 45% and 38% samples were found with AFM1 levels higher than the tolerance limits established by the European Commission and Food Safety and

Standards Authority of India, respectively [37]. Aflatoxin M1 (AFM1) contamination was investigated in 150 samples of milk sold in the market of Hisar City of Haryana, India, and 31 exceeded the maximum limit prescribed by FSSAI, India [38]. Analyses of 545 milk samples in Chhattisgarh, India found AFM1 contamination above the maximum permissible limits established by the European Commission and FSSAI in 21.3% and 4.4% of samples, respectively [39].

As the tested samples in the present study show low prevalence of aflatoxin residues as compared to other, similar Indian studies, one of the most plausible reasons could be good farming practices which are followed by the farmers. This may also have resulted from the dilution of the contaminated milk with good-quality milk as a part of the regular practice of pooling milk, resulting in the lowering of concentrations below the detection range of the kits. Only 37.7% of 300 surveyed farmers reported that they fed concentrate feed to their animals (Table 5). As discussed previously, concentrate feeds are primary causes of these residues; the management practice of limited or no concentrate feeding on the islands may have reduced the residues in milk samples. This is the first reported study on the Andaman and Nicobar Islands highlighting the prevalence of aflatoxin residues in the milk samples. As aflatoxin is an established carcinogen and health hazard, regular screening of the milk samples is recommended to ensure the safety of consumers, which is not presently a part of the tests conducted by the State Food Safety Laboratory, Port Blair.

Table 5. Knowledge, attitude, and practices (KAP) survey among the dairy farmers of Andaman and Nicobar Islands.

S. No.	Parameter	North & Middle Andaman	South Andaman	Nicobar	A&N Islands
	Farm Characteristics				
1.	Animal shed (Pucca)	37	57	25	39.67
2.	Farming practice—stall feeding	23	35	10	22.67
3.	Fodder development	16	18	3	12.3
	Herd Characteristics				
1.	Herd size (No.)	1.9	2.13	1.66	1.9
2.	Desi cattle (%)	33.7	16.4	30.7	26.93
3.	Per house hold production (L/Day)	6.49	7.4	5.5	6.46
4.	Per animal production (L/day)	4	4.14	3.7	3.95
	Feeding Management				
1.	Do you feed concentrate feed? (%)	42	61	10	37.67
2.	Is your feed compliant for aflatoxin residues?	0	0	0	0
3.	Do you know about aflatoxins in feed? (%)	0	0	0	0
	Reproductive Management				
1.	Are you able to detect animal heat timely?	19	29	5	17.67
2.	Do you use regular artificial insemination?	18	17	4	13
3.	Do you do pregnancy diagnosis for your cattle?	5	10	0	5
4.	Is any additional concentrate feed provided during pregnancy time?	25	28	3	18.67

Table 5. *Cont.*

S. No.	Parameter	North & Middle Andaman	South Andaman	Nicobar	A&N Islands
	Health management				
1.	Most common disease in your animals				
	Mastitis (%)	57	77	49	61
	Diarrhea (%)	12	8	15	11.67
	Infertility (%)	23	12	33	22.67
	Others (%)	8	3	3	4.67
2.	Do your practice regular deworming of your cattle?	4	8	0	4
3.	Do you give antibiotics to your animals without prescription?	0	0	0	0
4.	Do you know about the antibiotic residues in milk?	2	8	1	3.67
5.	Do you vaccinate your cattle (%)	0	97	0	32.33
	Milk Hygienic practices				
1.	Do you clean your hands before milking? (%)	40	65	43	49.33
2.	Do you clean your hands after milking? (%)	85	95	88	89.33
3.	Are the udders cleaned before milking? (%)	66	84	62	70.67
4.	Are the udders cleaned after milking? (%)	37	66	33	45.33
5.	Have you received training regarding the hygienic practices? (%)	0	0	0	0

3.4. Milk Safety Practices Followed by Farmers in A&N Islands

The KAP surveys can help to point out the inadequacies of the existing system and to provide corrective feedback to overcome the shortcomings. In this study, an assessment of KAP among the dairy farmers of the Andaman and Nicobar Islands was attempted, with focus on the milk hygiene practices. This assessment is presented in Table 5.

In this study, an assessment of Knowledge Attitude and Practices (KAP) among the dairy farmers of the Andaman and Nicobar Islands is attempted, with focus on the milk hygiene practices, based on the survey of 300 dairy farmers (Table 5). Practicing milk safety practices not only has beneficial effects on the quality of milk produced, but also on animal health and productivity. There have been no previously reported studies regarding detailed milk safety practices followed by dairy farmers of the A&N Islands.

Based on the current survey, at the UT level, the average herd size is 1.9, with about 26.9% of the animals rearing desi (non-descriptive) cattle and characterized by low production levels of 3.95 L/day. This is above the reported per capita production status of 2.9 kg/day which may be due to the averaging effect resulting from the impact of unproductive animals on the total milk production in the islands. Only 39.67% of farmers have dedicated cattle sheds for dairy animals, and 22.67% provide stall feeding to animals. The farmers who reported that they had their own fodder plots comprised only 12.3%. This may result in missing heats of animals and promoting natural service, as most of the time, animals are let loose for grazing. As a result, the artificial insemination rate is only 13%. Regarding the health aspects of the cattle, mastitis was reported to be the leading and most often recurring disease by 61% of farmers, followed by infertility, at 22.67%. Animals are fed concentrate feed only by 37.7% of the farmers, and additional rations during pregnancy are only fed by 18.67% of the farmers. Vaccination of the cattle is restricted to the South Andaman district, and 97% of farmers reported to have their animals vaccinated. However, regular deworming of the cattle is only conducted by 4% of farmers. Awareness about the withdrawal periods and antibiotic residues was very poor among the farmers, at the level of only 3.7%. Additionally, none of the farmers reported that they used any type of antibiotics without the prescription of veterinary staff. This may be one of the reasons that the samples were found negative for antibiotic residues. Furthermore, it was reported that none of the farmers had received training on the clean/hygienic milk production. The milkers reporting that they clean their hands before and after milking comprised 49.3% and 89.3% of participants, but the cleaning of the udder both before and after was only reported by 70.67% and 45.33%. The detailed district-wise distribution is depicted in Table 5. All the farmers reported to be using the hand milking method. During hand milking, the producers are in very close contact with their animals, which increases the risk of transmission of disease from the animal. One major source of disease-causing bacteria is the feces from the cow, and the milkers are likely to be highly and repeatedly exposed to this through their close contact. In this study, it was shown that normal farm water was the most common means of washing hands. No data were collected on the origin of the water, but it has been shown that water stored in tanks may contain much higher levels of bacteria than tap water. All the farmers washing their hands or cleaning the udder, either before or after the milking, reported that they used water. No one claimed to use soap or disinfectant. On the question of whether farmers were aware of the diseases that may be transmitted between dairy cows and humans, some of the farmers replied affirmatively that they believed in such transmission, but none of them were able to name any disease. However, some said that consuming infected milk may lead to diarrhea and vomiting in the consumers. Hence, the responses were recorded as negative.

Based on the results, the present awareness among the farmers regarding the quality aspects can be considered as poor. Similar studies from other regions of India have indicated that dairy farmers largely neglected the impact of cleanliness on the animal's udder and health, and were ignorant about the milk contamination causing health hazards [40]. It has been shown experimentally that when hygienic practices are followed, the microbial contamination is significantly reduced [41]. Researchers opined that thorough washing of the milkers' hands with clean water, as well as trimming of their nails to prevent injuries to the teat, caused reduced incidence of sub-clinical mastitis [42]. The study conducted in the R. S. Pura block of Jammu district revealed that daily cleaning of the animal house was adopted by the majority (92.50%) of the respondents, and very few (27.50%) respondents had constructed a pucca floor or a drainage system in the animal shed. A very low percentage (22.50) of respondents washed udders to remove mud and dung. Not a single respondent practiced post- and pre-milking tip dipping in potassium permanganate solution. All the respondents (100%) washed their hands with plain water before milking and trimmed their nails regularly. Only 12.5% had adopted the practice of passing the milk through a sieve or muslin cloth for the removal of dirt [43]. Poor hygiene practices at the farm level have been reported to be the main cause of poor productivity and income losses for the smallholder sector [43]. Another KAP study in Assam concluded that the knowledge levels with regard to hygiene and disease were very low among dairy producers and traders [44]. The detailed district-wise results of the farmer survey for the A&N islands are discussed below:

i. North and Middle Andaman

The average herd size of adult cows for the farmer household is 1.9, the average milk production per household is 6.49 L/day, and the average per animal production is 4 L/day. Only 33.7% of the animals in the sample population are desi, and the rest are cross-bred animals. Of the farmers who were surveyed, 42% claimed to feed concentrate feed to their cattle, but none of them were aware of the potential aflatoxins in the milk. The most common disease in the animals was mastitis, followed by infertility. None of the farmers reported having any information regarding the vaccination of their animals.

Regarding the hygienic practices being followed, 40% and 85% of farmers reported to clean their hands before milking and after milking, respectively. Furthermore, they reported that they use only water, and no specific disinfectant or soap. In addition, 66% and 37% reported that they clean the udder before and after milking, respectively. However, no specific use of any medicated soap or disinfectant was reported by any farmer, and only water was reported to be used for these purposes.

ii. South Andaman

The average herd size of adult cows for a farmer household is 2.1, the average milk production per household is 7.4 L/day, and the average per animal production is 4.14 L/day. Only 16.4% of the animals in the sample population are desi, and the rest are cross-bred animals.

About 61% of farmers claimed to feed concentrate feed to their cattle, but none of them were aware of the potential aflatoxins in the milk. The most common disease in the animals as mastitis, followed by infertility. Of the farmers who were surveyed in the South Andaman district, 97% claimed to have vaccinated their animals biannually for Foot and Mouth Disease.

Regarding the hygienic practices being followed, 65% and 95% of farmers reported to clean their hands before milking and after milking, respectively. However, they reported that they use only water, and no specific disinfectant or soap. In addition, 84% and 66% reported that they clean udder before and after milking, respectively. Further, no specific use of any medicated soap or disinfectant was reported by any farmer, and only water was reported to be used for these purposes.

iii. Nicobar

The average herd size of adult cows for a farmer household is 1.7, the average milk production per household is 5.5 L/day, and the average per animal production is 3.7 L/day. Only 30.7% of the animals in the sample population are desi, and the rest are cross-bred animals.

About 10% of farmers claimed to feed concentrate feed to their cattle, but none of them were aware about the potential aflatoxins in the milk. The most common disease in the animals was mastitis, followed by infertility. None of the farmers reported that they had any information regarding the vaccination of the animals.

Regarding the hygienic practices being followed, 43% and 88% of farmers reported to clean their hands before milking and after milking, respectively. However, they reported that they use only water, and no specific disinfectant or soap. In addition, 62% and 33% reported that they clean the udder before and after milking, respectively. Furthermore, no specific use of any medicated soap or disinfectant was reported by any farmer, and only water was reported to be used for these purposes.

The results show that the present awareness among the farmers of the A&N Islands regarding the quality aspects of milk can be considered poor. However, this may not be resulting in potential outbreaks of diseases, as most of these regions of the A&N islands are naturally disease-free, due to geographical isolation providing a natural quarantine, and thus carry lower microbial load.

4. Discussion

The results of this study provide a snapshot and, likely, the first picture of the present status of dairy in the Andaman and Nicobar Islands. The results highlighted that the huge deficit in the local milk production is associated with the inflated pricing, which limits the physical and economic access of the masses to milk and milk products. In addition to this, as reported, 57.8% of the milk samples in the A&N Islands were found to be adulterated and misbranded in 2017–2018. However, during the National Survey on Milk Quality, 2018, which collected 14 samples for the testing from the region, none of them were found to be substandard. Thus, a significant difference exists in the results of milk samples processed in the national survey and the reports of the local food safety laboratory. In addition, considering the high proportion of over 99% of milk being handled by the unorganized sector, the chances of quality compromise may be high, and, thus, require regular monitoring and screening. Local screening is limited to the basic adulteration tests. Even the Parliamentary Standing Committee on Health and Family Welfare, Government of India is not convinced by the sampling procedure, analysis time, and protocols followed in the national milk quality surveys conducted by FSSAI in 2011 and 2016, as they were not uniform. The Committee has observed that "a precise and accurate conclusion out of survey(s) can be drawn only with appropriate sample size. The sample size of 1791 and 1663 in the surveys of 2011 and 2016 were not adequate. Taking into account the size of population and the quantity of milk produced in the country, the Committee would, therefore, exhort the Ministry to ensure that in future the sample size of such surveys should be appropriate and truly representative. The Ministry has to ensure that protocols followed for such surveys are uniform so that they lead to valid conclusions [45]".

The cows of the A&N islands may be divided into local, trinket, and cross-bred cattle [46]. The local cattle of Andaman are nondescript, and represent mixed inheritance from different breeds that were brought into the islands. The Trinket cattle available on Trinket Island have an exotic heritage that can be traced back to Danish people, who had settled in 1756–1768 in a part of the Nancowrie group of islands [47]. The cross-bred cattle are the crosses of local cattle with Jersey or Holstein–Friesian. Out of these cattle, the local and cross-bred are domesticated while Trinket cattle are feral in nature. The results of our study, which show high value of the A2 allele are compatible with the results of similar studies [48] on the beta-casein variants among 15 Indian cattle breeds, as the frequencies of A2 allele were 0.904 in Malnad Gidda and 0.891 in Kherigarh. Fixation of the allele was found in in Kangayam, Nimari, Red Kandhari, Malvi, Amritmahal, Kankrej, Gir, Sahiwal, Hariana, Tharparkar, Rathi, Mewathi, and Red Sindhi with the absence of the A1A1 genotype. The predominance of the A2 allele has also been reported in Sahiwal, i.e., 0.93 in Sahiwal [49] and 0.94 in Ongole [50]. Malarmathi et al. (2014) did not find any A1 alleles, and reported that the A2 allele had been fixed in the Kangayam breed of cattle of Tamil Nadu [51]. Ramesha et al. (2016) screened the various breeds of cattle of India and reported the frequencies of the A2 allele as 0.986 in Malnad Gidda, 0.958 in Kasargod cattle, and 1 (fixed) in the Deoni and Khillar cattle breeds [52]. Kumar et al. (2018) also reported the abundancy of the A2 allele in Sahiwal cattle, and the frequencies of A1 and A2 alleles were 0.06 and 0.94, respectively, with the absence of the A1A1 genotype in the population that they studied [53]. The frequencies of alleles A1 and A2 were 0.063 and 0.937 in the Bargur breed, and 0.024 and 0.976, respectively, in the Umblachery breed [54]. A similar study revealed that all three types of genotypes, viz. A1A1, A2A2, and A1A2, were present in the Vrindavani cross-bred population, with genotypic frequencies of 12.3%, 39.6%, and 48.1%, respectively [53].

All the leading brands of dairy in the Indian market market their milk and milk products with A2 milk as a premium product, with high prices [55–58]. However, the FSSAI has not yet established a definition, standards, or certifying procedure for such A2 products. Additionally, the options available to consumers with regard to food fraud related to this issue are extremely limited [59]. Thus, our findings suggest that the claims that products in the Indian market consist of A2 milk and milk products are questionable, due to lack of standardization protocols and certifications.

As per the interim report of the Milk Survey, 2018, conducted by FSSAI, the antibiotic and aflatoxin residues are contributory factors, accounting for 70% of the total unsafe samples. In the same survey, all of the samples from the A&N Islands were found to be negative for both. However, as per their regular practice, the Food Safety Laboratory, Port Blair only processes the milk samples for common adulterants. Even with these tests, 48.2% of the milk samples do not meet the requisite quality parameters of FSSAI. With this background, the milk samples were screened for antibiotic and aflatoxin residues using the LFT-based Charm ROSA kits.

As the tested samples were all found to be negative in terms of antibiotic residues, further studies are needed to investigate the reason for this. It may be due to good farming practices, or may have resulted from dilution of the contaminated milk with good-quality milk as a part of the regular practice of pooling milk, resulting in the lowering of concentrations below the detection range of the kits. The fact that most of the farmers have small holdings and operate within very small margins of profits, coupled with the lack of availability of antibiotics in the open market, may have reduced the consumption of non-prescribed antibiotics and, thus, lowered the levels of residues in milk. But as these residues are potential health hazards, regular screening of the milk samples is, therefore, required to ensure the safety of the consumer. This study shows the prevalence of aflatoxin residues in the milk samples of the Andaman and Nicobar Islands. As aflatoxin is an established carcinogen and health hazard, regular screening of the milk samples is, therefore, required to ensure the safety of the consumer.

The study shows that the awareness of the quality aspects of antimicrobial residues, withdrawal timings, aflatoxins, etc., are highly limited among the farmers of the region. There have been no reported studies published regarding the detailed milk safety practices of the islands until now, and, therefore, it is very difficult to perform a comparative analysis of the results with the previous studies in this region. Thus, necessary comparisons were drawn to the national average. Similar studies in India have indicated that dairy farmers largely neglect the impact of cleanliness on animals' udders and health. Poor hygiene practices at the farm level have been reported to be the main cause of poor productivity and income losses for the smallholder sector. The same is evident from the results in the present study. Thus, following the milk safety practices not only has beneficial effects on the quality of the milk produced, but also on health and productivity of the animals.

5. Conclusions

Milk and milk products form an integral part of the diet in India, and different stakeholders raise severe concerns about the requisite quality and quantity required to ensure the food security of the population. As per the present study, although national milk production has been reported to be above the recommended value by different agencies, regional insecurities still exist from a food security perspective. This study evaluates the Andaman and Nicobar Islands scenario and highlights the issues. The regional milk availability from local milk production has an annual deficit of 23,673.6 metric tons. The geographical isolation of the region adds to the vulnerability of the existing supply chain, making the region food insecure from a dairy perspective. Furthermore, 55.3% of the milk samples failed the basic quality tests, and did not meet the standards as assessed by the reports of the State Food Laboratory, A&N Islands. With a considerable deficit in the local milk supply chain, which is further characterized by a lack of tracking and traceability, food security is compromised in the Andaman and Nicobar Islands from a dairy perspective. It requires the immediate attention of the governing bodies.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su15010206/s1, Figure S1: Genotypes of beta-casein in the samples (3.5% agarose gel), M: 100 bp DNA ladder.

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