Abstract — Traditional Human Milk Bank systems face challenges in maintaining data integrity, data transparency and data security. Hence, there is a lack of trust in traditional distribution system. To address this challenge, we have come up with a blockchain based solution for Human Milk banks.

Keywords — donor, pasteurization, serology, transparency, security

1. INTRODUCTION

Human Milk distribution (HMD) system is a blockchain based application to track the administration of human milk bank. The process of Human milk distribution chain deals with highly sensitive data such as Donor serological clearance, Pasteurization, Microbiology and several other records. Blockchain ensures storage of these records in a secure and transparent manner. It also enables effective end to end traceability.

2. TRADITIONAL HUMAN MILK DISTRIBUTION

A. Necessity of Human Milk Banks (HMB)

Breastfeeding is the best method of infant feeding because human milk continues to be the only milk which is tailor-made and uniquely suited to the human infant. Human Milk Banks cater to the need for pasteurized donor human milk (PDHM) when mother’s own milk is unavailable or insufficient. Human milk is of utmost importance in following cases

- Low birth weight babies, preterm and sick babies

B. Risks Involved in Traditional Human Milk Bank Management

Human milk bank deals with various donors and milk processing stages. There are many stages where risks are involved and some of them are mentioned below.

- Donor Tests – Human milk is a carrier of many serious diseases from mother to child. So tests are conducted periodically for various conditions. Few of which are listed below:
  - HIV 1 & 2
  - Hep B
  - Hep C
  - Syphilis

- Microbiological screening of donor milk is done before and after pasteurization.
  - A bacterial count of 105 CFU/mL or more in raw breastmilk can be considered as an indicator of the poor quality of milk.
  - No growth is acceptable in post-pasteurization microbiology cultures. Whole batch of culture positive pasteurized milk should be discarded.

3. PROPOSED SYSTEM – BLOCKCHAIN BASED HUMAN MILK DISTRIBUTION

The proposed system employs distributed ledger, which makes data immutable and transparent. The following are the stages involved in milk bank (MB) process:

A. Donor Registration

In this process, donor details and her eligibility criteria will be captured. The following diagram explains the steps involved in donor registration.

Fig: Donor registration process

B. Donor Milk Collection

The donor collects raw breast milk and stores it either in empty bottles provided by the Milk Bank (MB) or their own containers. The milk is attached with a unique code to track throughout the process.
C. Milk Processing

Raw Milk (Received Raw units) is batched into standard units and is labelled with QR labels before being processed. During pasteurisation, the temperatures are measured and monitored. Post which, the samples are tested and the results are recorded in blockchain database. Below are the stages of milk processing and the appropriate data is captured:

A. Thawing raw milk – The thawing process takes place in three ways: 37°C Oscillating Incubator, Refrigerator and Room temperature.

B. Aliquots division - Raw milk batches are divided into aliquots (bottles) of 50 ml, 130ml or 250ml. Each aliquot will be labelled with the respective QR code for traceability.

C. Pasteurisation - This process can be done for a pool of aliquots or single aliquot. During this process, a report will be generated which contains start time, end time and temperature logged periodically. The same is stored into our system through which it can be audited to comply with the suggested safety guidelines.

D. Microbiology control - Pre and Post pasteurisation tests measure the microorganisms which are present in the milk before and after pasteurisation. The same is stored into our system for further monitoring.

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Test Result</th>
<th>Test Result</th>
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</thead>
<tbody>
<tr>
<td>S1</td>
<td>Pre-pasteurisation: Negative</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>Post-pasteurisation: Negative</td>
<td>Pass</td>
</tr>
<tr>
<td>S2</td>
<td>Pre-pasteurisation: Positive</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>Post-pasteurisation: Negative</td>
<td>Pass</td>
</tr>
<tr>
<td>S3</td>
<td>Pre-pasteurisation: Negative</td>
<td>Repeat Post-pasteurisation test</td>
</tr>
<tr>
<td></td>
<td>Post-pasteurisation: Indeterminate/Unacceptable</td>
<td>Repeat Post-pasteurisation test</td>
</tr>
<tr>
<td>S4</td>
<td>Pre-pasteurisation: Positive</td>
<td>Repeat Post-pasteurisation test</td>
</tr>
<tr>
<td></td>
<td>Post-pasteurisation: Indeterminate/Unacceptable</td>
<td>Repeat Post-pasteurisation test</td>
</tr>
</tbody>
</table>

E. Application Flow

4. Benefits of this Application

Milk bank administration desires to keep crucial data of Donors, pasteurisation process, microbiological control tests, making it immutable and transparent to the end user. Blockchain is best suited technology for this use case. The following are the few advantages for various users in the system.

A. Donor can schedule appointments for Donations

B. Serological and various other clearance details are meticulously captured and tracked till the end.

C. Application is developed using HIPAA standards, so that it is suitable for use by milk banks all over the world

D. High degree of confidence in integrity of the donor serological reports, pasteurization parameters, pre and post pasteurisation results, expiry date etc.

5. Samvaadak – Our Blockchain Library

Samvaadak powered by Nviera is a leader based consensus algorithm. It avoids many overheads that are present in traditional leader based algorithms.

Traditional Leader based algorithms have many demerits such as:

- Election for Leader: In many scenarios, due to the network latency, the leader node may fail to respond to any of the other nodes in the network causing collection, pasteurization reports and other details by scanning the QR code.
unnecessary polling for leader. This causes huge network traffic and congestion.

- **DDoS Attacks:** Leader based algorithms are vulnerable to large delays due to denial of service attacks on the leader. This may compromise the whole system.

- **Single point of failure:** In many leader based algorithms, the designated leader node is responsible to conduct voting and commit phases for all the transactions. This may lead to a single point of failure since leader node experiences extensive load from the network.

In Samvaadak the merits are:

- Leader is chosen, not elected: Election causes unnecessary traffic in the network. However, in Samvaadak, the Leader is chosen by the initiator of the transaction. This avoids much traffic, which helps in reduction of network latency and improves performance.

- Leader is chosen in round robin fashion: For each transaction a different node will be chosen as a leader. The leader is chosen in a round robin fashion which helps in distribution of load evenly and minimizes the single point of failures.

- Nodes are tightly coupled: Backend nodes will not accept any other connections except from their family members (Known nodes). This is achieved by using a handshake protocol among the nodes. Hence the chances for DDoS are reduced. Moreover, since the leader keeps changing for each transaction, it is even harder to target any one particular node for DDoS attack. Also Nodes which are exposed to Internet are will be protect by firewall.

**Consensus Mechanism:**

The nodes are classified in two categories as mentioned below

- **Front-End Nodes:** These nodes receive user requests and responsible for initiating consensus. It will also choose the leader to execute the consensus.

- **Back-End Nodes:** Responsible to perform voting and committing phases for a transaction.

Front-end node will receive a HTTP request and validates the payload to ensure that the presented data is correct and adequate

The Front-end node chooses a node from the Backend pool as a leader and submits the request for consensus execution and eventual commit

The selected Back-end node (also called as the Leader) creates a new Consensus transaction for the request

Leader sends out messages for Voting on the subject of the request

The rest of the nodes process the voting request sent by the leader node. Based on the business rules defined, they perform the validations and submit their vote responses back to the leader

Leader node computes the outcome of the voting and if positive, performs the phase 2 (commit phase) of the operation. This involves creating a new block in the Blockchain

6. **BLOCKCHAIN DATABASE**

Blockchain Database contains threads of transactions called Strands. Each transaction is considered as block and linked using strand ID. Each committed transaction will create a new Block. Every block contains three parts which are listed below

- **Header:** Contains the current block hash, previous block hash & the timestamp

- **Meta:** Contains the Node IDs, which are voted for this transaction to be committed

- **Payload:** This is related to business use case, on which the consensus rules are applied to take decision at the time of voting
Every block is linked to previous block of same strand ID using SHA256.

7. TRANSACTION FLOW

The following are classification of data captured in this solution.

1. Donor Blockchain
2. Milk Bank Blockchain
3. Recipient transactions Blockchain.

A. Donor Blockchain

The above diagram show the data captured in blockchain for Donor registration

1. Donor registration - For every new donor a new strand is created with genesis block carrying the following data
   a. Unique ID
   b. Donor Name
   c. KYA Document Hash – Document stored in file storage and the hash of the document is stored in the block. While retrieving the document is verified against the hash stored in the block.
   d. Date of Birth
   e. Nationality
   f. Email Address
   g. Contact Number

2. Donor serology clearance - A block subsequent to donor registration block will be created. Serology test is repeated every 3 months and a new block will be created and linked to existing chain. The following data is captured in the block.
   a. Date & Place
   b. Lab Information
   c. Blood Test ID
   d. Tests reports – reports are scanned
      i. HIV 1 & 2 result.
      ii. Hep B result
      iii. Hep C result
      iv. Syphilis result
   e. Milk Bank Authority ID (user who authorises the donor)

B. Milk Bank Blockchain

Milk Bank Blockchain involves in capturing data in the following stages.

The above diagram depicts the milk processing stages and data captured in each stage.

1) Raw Milk Collection – Data captured is listed below.
   a) Raw milk ID
   b) Donor Unique ID
   c) Collection Date and Time
   d) Receiving Site
   e) Breast Pump Type
   f) Unit volume
   g) Number of units
   h) Total volume
   i) Unit ID

2) Batch Mixing
   a) Raw Milks : <Array of IDs>
   b) Aliquot Unit ID : <Array of IDs>
   c) Mixing Date
   d) Aliquot Unit volume
   e) Aliquot Unit quantity

3) Pasteurization
   a) Pasteurisation Batch Id
   b) Aliquot ID
   c) Date
   d) Pasteurisation Index
   e) pre pasteurisation result
   f) post pasteurisation result

C. Recipient Blockchain

1. Recipient Registration – Data captured is listed below
Aliquot Receipt – Data captured is listed below
a. Recipient ID
b. Aliquot ID
c. Date and Time
d. Location

8. CONCLUSION
This solution considers all risk factors such as donor test reports, pasteurisation reports, storage of milk information and expiry dates etc., and brings more transparency and integrity by capturing the crucial data in all stages using blockchain. Since the end recipients are infants, quality cannot be compromised. QR code on every dispensed milk bottle can be used to view entire history of the milk, which brings transparency and drives confidence in distribution chain.

9. REFERENCES
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