SUMMARY AND CONCLUSION

The investigation was undertaken considering the importance of energy saving and nutritional value of the food products. Due to the competitive market, it is very important to reduce the processing cost of the product, so that the nutritious food is made available at the cheaper rate in the market. The denaturation of the protein takes place at higher temperature of drying. Lowering the drying temperature in the spray drier chamber minimizes denaturation of protein and further drying in fluidized bed at lower temperature maintains the functional properties and gives the better agglomeration properties without further denaturation of protein. The buffalo milk contains more fat and SNF per unit volume. Therefore, processing plants are required to handle lesser quantities of buffalo milk to obtain same production level.

The review of literature concerning the spray drying of Skimmed Milk Powder and WPC with regard to the protein denaturation and storage studies of WPC scanned in the preceding chapter indicated that there are hundreds of dryer designs available in the market at present. Cronshaw (1926) made an attempt based on the form of the material being handled and the means by which material is transferred through the drier as the basis. Most thorough classification of drier type has been made by Kroll (1965) who has
a decimal’s system based on the factors like temperature, pressure, method of heating, method of air circulation, heating medium, nature of the wet feed introduced into the dryer. A summary of drier types together with cost data has been presented.

Drying means that the water in a liquid product, in this case whey protein concentrate is removed so that the product acquires a solid form. The water content of product ranges between 2.5 and 5.0 % and no bacterial growth occurs at such low water content. Drying extends the shelf-life of WPC liquid simultaneously reducing its weight and volume. This reduces the cost of transportation and storing the product. Commercial methods of drying are based on heat being supplied to the product, water is evaporated and removed as vapour .The residue is the dried product .For drying the WPC powder, two principal methods are used in the dairy industry, roller drying and spray drying. In spray drying the WPC retentate obtained from UF at different TS is dried in spray drier.

In the past, the typical inlet and outlet temperatures of milk dryer were 356 and 203°F (180 and 95°C), respectively. Newer designs have increased the inlet temperature to 428°F (220°C) or higher and reduced the outlet
temperature to around 185°F (85°C). This change has been made possible by the development of multistage drying systems. (Stewart Gibson, 2004)

The literature was scanned for the storage stability of WPC at various temperatures and relative humidities for change in acidity, pH, flavour, colour and bacteriological quality indicated that so far no work has been carried out for the energy optimization for spray drying of WPC-70 from buffalo milk and subsequent storage stability at various temperatures and humidities.

In the materials and methods the experiment was divided into five phases.

3.9.3 Standardization of buffalo milk and its separation.

3.9.4 Coagulation of skim milk and collection of wash water and whey.

3.9.5 Clarification & pasteurization of whey and feed to UF plant.

3.9.5.13 Spray drying of WPC-70 with single stage, double stage and three stage process.

The buffalo milk was standardized to 8.5% SNF, the fat in the skimmed milk was <0.05%. It was pasteurized at 75°C for 15 Sec. and chilled to 4°C.

The milk was then coagulated after pre-heating to 35°C by addition of 12%HCL, then heating to 45°C for complete coagulation. The mass was passed through a decanter where the pure whey was obtained. pasteurization
at 74°C/15 sec, cooling to 16°C and passing through ultrafiltration plant (5 stage). The experiment was conducted as follows:

1. Effect of diafiltration water on Total Solids.
2. Effect of feed: product ratio on protein level.
3. Effect of preheating temperature on protein denaturation.
4. Energy consumption/ cost calculation in single stage dryer.
5. Energy consumption/ cost calculation in two stage dryer.
6. Energy consumption/ cost calculation in three stage dryer.
7. Effect of spraying nozzles on particle size distribution.
8. Effect of chamber vacuum on the size of agglomerates.
9. Effect on energy consumption by using superheated steam.

1. Effect of diafiltration water on Total Solids

The whey when passed through the ultrafiltration plant, the diafiltration water was added at 21%, 22%, 23%, 24%, 25%, 26%, 27%, 28%, 29%, 30%. The best result was obtained at diafiltration water 27% where the protein level was 70% and the flux was very good.

2. Effect of feed: product ratio on protein level.

The ratio of product feed was adjusted with the help PID controlled valve and the ratio was adjusted at .015, .016, .017, .018, .019 and .020. It was
observed that the best protein level of WPC-70 was obtained at Product: Feed ratio is .018 at 27% diafiltration water.

3. Effect of preheating temperature on protein denaturation.

The WPC-70 was pre-heated at the temperature 55°C, 57°C, 59°C, 60°C, 63°C, 65°C, 67°C, and 69°C. It was observed that the optimum temperature for pre-heating of the WPC-70 before the feed to the dryer is 59°C, which gives the economy for the drying as well as the protein denaturation is within the limits i.e. 0.6%

Energy consumption/ cost calculation in single stage, two stage and three stage drier dryer.

The Drier was run with the following standardized feed of WPC with Single Stage, Two-Stage (External Fluidized Bed) and Three-Stage (External Fluid Bed and Integrated Fluid Bed).

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Protein</td>
<td>70%</td>
</tr>
<tr>
<td>2.</td>
<td>T.S</td>
<td>21%</td>
</tr>
<tr>
<td>3.</td>
<td>Inlet temperature</td>
<td>182°C</td>
</tr>
<tr>
<td>4.</td>
<td>Pre-heating temperature</td>
<td>59°C</td>
</tr>
<tr>
<td>5.</td>
<td>Final moisture</td>
<td>2.8%</td>
</tr>
<tr>
<td>6.</td>
<td>Atomized pressure</td>
<td>170kg/cm²</td>
</tr>
<tr>
<td>7.</td>
<td>Outlet temperature Single Stage</td>
<td>97°C</td>
</tr>
<tr>
<td>8.</td>
<td>Outlet temperature Double Stage</td>
<td>72.5°C</td>
</tr>
<tr>
<td>9.</td>
<td>Fluid bed temperature (heating section)</td>
<td>75°C</td>
</tr>
<tr>
<td>10.</td>
<td>Fluid bed temperature (cooling section)</td>
<td>25°C</td>
</tr>
<tr>
<td>11.</td>
<td>Integrated bed temperature</td>
<td>80°C</td>
</tr>
</tbody>
</table>
# Drying Cost Comparison for Single Stage/Double Stage and Three Stage Drying (Integrated Bed)

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Parameter</th>
<th>Single Stage</th>
<th>Double Stage</th>
<th>Three Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Inlet Air Temp. °C</td>
<td>182°C</td>
<td>182°C</td>
<td>182°C</td>
</tr>
<tr>
<td>2</td>
<td>Outlet Air temp. °C</td>
<td>97°C</td>
<td>72.5°C</td>
<td>68.5°C</td>
</tr>
<tr>
<td>3</td>
<td>Quantity of air Kg /Hr</td>
<td>19865.73</td>
<td>20247.69</td>
<td>20102</td>
</tr>
<tr>
<td>4</td>
<td>Steam Consumption at 15 Kg /cm²</td>
<td>1316</td>
<td>1316.28</td>
<td>1316.55</td>
</tr>
<tr>
<td>5</td>
<td>Heat requirement (Kcal/Hr)</td>
<td>667475</td>
<td>668933.50</td>
<td>670386.3</td>
</tr>
<tr>
<td>6</td>
<td>Moisture Content % of WPC Powder</td>
<td>2.8</td>
<td>5.5</td>
<td>7.0</td>
</tr>
<tr>
<td>7</td>
<td>% Solids of WPC</td>
<td>21</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>8</td>
<td>Quantity of WPC Kg./hr</td>
<td>685</td>
<td>827.46</td>
<td>882</td>
</tr>
<tr>
<td>9</td>
<td>WPC Powder Output Kg./hr.</td>
<td>147.84</td>
<td>183.88</td>
<td>199.18</td>
</tr>
<tr>
<td>10</td>
<td>Water evaporation Kg./hr</td>
<td>537.16</td>
<td>643.58</td>
<td>682.90</td>
</tr>
<tr>
<td>11</td>
<td>Steam Consumption Kg./Kg powder</td>
<td>2.45</td>
<td>2.04</td>
<td>1.93</td>
</tr>
<tr>
<td>12</td>
<td>Heat Consumption Kcal./Kg powder</td>
<td>1246.57</td>
<td>1039.39</td>
<td>981.67</td>
</tr>
<tr>
<td>13</td>
<td>Power Consumption Kwh.</td>
<td>56.89</td>
<td>57.5</td>
<td>57.09</td>
</tr>
</tbody>
</table>

**Total: VFB + Integrated Bed**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Parameter</th>
<th>VFB</th>
<th>Integrated bed + VFB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Inlet Air Temp. °C</td>
<td>78°C</td>
<td>72°C</td>
</tr>
<tr>
<td>2</td>
<td>Moisture in the powder (%)</td>
<td>2.8</td>
<td>5.5</td>
</tr>
<tr>
<td>3</td>
<td>Powder quantity(Kgs)</td>
<td>178.77</td>
<td>186.22</td>
</tr>
<tr>
<td>4</td>
<td>Water Evaporation(Kgs)</td>
<td>5.11</td>
<td>2.78</td>
</tr>
<tr>
<td>5</td>
<td>Steam Consumption(Kgs)</td>
<td>16.0</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>Power Consumption((Kwh))</td>
<td>8.11</td>
<td>4.0</td>
</tr>
<tr>
<td>7</td>
<td>Steam Consumption (Kg./hr).</td>
<td>1316</td>
<td>1332.22</td>
</tr>
<tr>
<td>8</td>
<td>Power Consumption (Kwh.)</td>
<td>56.89</td>
<td>65.61</td>
</tr>
<tr>
<td>9</td>
<td>Powder production (Kgs).</td>
<td>147.84</td>
<td>178.77</td>
</tr>
<tr>
<td>10</td>
<td>Cost of Steam (Rs.)</td>
<td>544.40</td>
<td>533.20</td>
</tr>
<tr>
<td>11</td>
<td>Cost of electricity (Rs).</td>
<td>227.56</td>
<td>262.40</td>
</tr>
<tr>
<td>12</td>
<td>Cost Of steam/Kg powder (Rs).</td>
<td>3.68</td>
<td>2.98</td>
</tr>
<tr>
<td>13</td>
<td>Cost of Electricity/Kg. powder (Rs.)</td>
<td>1.54</td>
<td>1.47</td>
</tr>
<tr>
<td>14</td>
<td>Total energy Cost (Rs.)</td>
<td>5.22</td>
<td>4.45</td>
</tr>
<tr>
<td>15</td>
<td>Dryer Efficiency(%)</td>
<td>54.14</td>
<td>69.74</td>
</tr>
</tbody>
</table>
It is concluded from the above that single stage drying was less efficient than the double and three stage drying. The cost of the drying was less by 14.7% in double stage and 24.5% in three stage drying. In addition to the quality of the powder which was having negligible denaturation of protein and best functional properties. The above parameters were found to be best operating conditions for the minimum energy cost, without affecting the nutritional and functional properties of WPC 70.

1. The best nozzle combination for the particle size distribution was from M/s Delavan. Delta Inc. nozzle orifice no. 703-127 with swirl chamber letter SG.

2. The optimum vacuum in the spray drying chamber was 10 mm during the fine recirculation for the best agglomeration of WPC-70 powder.

3. There was net saving of 5% by using superheated steam in the radiator as compared to the saturated steam at the same pressure.

Storage stability of the product at 38°C/65% RH, 24°C/60%RH, 6°C/50%RH.

The following parameters were taken into account.

1. Effect on pH and acidity.

2. Effect on moisture content.
3. Effect on solubility index.

4. Effect on whey proteins.

5. Effect on Non-Protein Nitrogen.


7. Effect on sensory changes.: Flavour, colour and appearance.

Various physico-chemical changes occurring in WPC were monitored at predetermined time intervals (on alternate month up to 10 months for product stored at 38°C / 65% R.H., on every second month up to 14 months for product stored at 24°C / 60% R.H and on every alternate month up to 18 months for refrigerated product) till the product was found unacceptable, scoring less than 60 percent marks on sensory evaluation (IS:6273 Part-II, 1971). Various other parameters evaluated were pH, titratable acidity, fat, whey proteins, NPN, lactose, total ash, denatured whey protein, chloride and calcium. The microbiological status of fresh and stored samples was also assessed. For this investigation, seven replicates were carried out to assess storage-related changes and for deciding shelf-life of WPC-70 at various storage temperatures.

**Effect on pH and acidity.**
Physico-chemical: The result of this investigation showed that the product stored at higher temperature 38°C / 65% R.H., resulted in increased pH at 4th month and then a continuous decrease was observed. The product stored at (24°C /60% R.H) also showed similar trend in pH as 38°C / 65% R.H, temperature. However storage temperature at 6°C/ 50% R.H, observed sharp increase in pH at 2nd month and afterwards subsequent decrease was observed throughout the experiment. This increase in pH at 4th month may be because of intermolecular association between alpha-la and beta-lg molecules resulting in high molecular weight aggregates (Li-chan, 1983). Partial heat denaturation, caused by heat treatments during the production of WPC during processing makes protein solubility much more sensitive to the effect of pH and salts (deWit, 1983). Similar changes of decrease in pH during storage at 30°C and 40°C for 18 months have also been reported in non-fat milk powders (Kieseker and Clarke, 1984), and Kathleen et.al., 1949).

Changes in acidity:

The acidity of product stored at 38°C / 65% R.H., and 24°C /60% R.H gave similar trend except that rise in acidity was slower at 24°C /60% R.H temperature. However, the rise in acidity was started at 8th month and then
very slow increase occurred on product stored at 60°C/50% R.H up to 18th month as presented.

**STORAGE RELATED MOISTURE CHANGES**

The results of this investigation showed that the product stored at temperature 38°C/65% R.H, gave less increase in moisture as compared to 24°C/60% R.H. There was a slightly increase in moisture value of the product kept at 6°C/50% R.H. Maximum increase in moisture value was observed at refrigeration temperature as compared to other temperatures of storage. At the 10th month of storage, product showed 3.77, 4.08 and 4.21 percent moisture at 38°C/65% R.H, 24°C/60% R.H and 6°C/50% R.H, respectively. On storage of product at 18th month at 6°C/50% R.H, it was just 67.76 percent over initial value of moisture i.e. 3.04 percent.

**SOLUBILITY INDEX**

The S.I. showed similar trend which was observed in all the samples stored at different temperatures (Table-4.8). Significant effect was observed at 14th month i.e. 4.0 ml and 4.2 ml of 24°C/60% R.H and 6°C/50% R.H temperature respectively. Variation in S.I. observed was thus a function of storage temperature and period of storage.
TOTAL WHEY PROTEINS

4.3.2.6.4. The behaviour of total protein was studied during storage at different conditions. The data obtained showed that total protein content decreased during storage at 38°C / 65% R.H. The decrease was observed 0.4, 0.77, 0.4 and 0.44 percent at 2nd, 4th, 6th, and 8th month, respectively. At 24°C /60% R.H the decrease was 0.15, 0.61, 0.47, 0.42, 0.40, 0.47 and 0.32 percent at 2nd, 4th, 6th, 8th, 10th, 12th and 14th month, respectively. However, at 6°C/ 50% R.H, the behaviour of total protein at alternate month viz. 2, 4, 6, 8, 10, 12, 14, 16 and 18, a decrease in protein at the rate of 0.1, 0.36, 0.39, 0.15, 0.15, 0.20, 0.20, 0.25 and 0.20 percent was observed from each even month.

The data of total protein showed that at higher temperature reduced the protein content at higher rate as compared to three storage temperature, the reduction were least at 6°C/ 50% R.H temperature. At 38°C / 65% R.H and 24°C /60% R.H the reduction in total protein was maximum at 4th month. At 6°C/ 50% R.H temperature, the reduction was maximum at 6th month.

NON-PROTEIN NITROGEN

The changes in WPC NPN during storage at different temperatures showed increasing trend at every alternate month of the samples stored at different
temperatures. At 38°C / 65% R H the NPN was found to be 0.18 percent at the day of manufacturing. The increase in NPN was found to be almost constant after every two month. The NPN was 0.51 percent on 8th month. At 24°C /60% R.H the NPN also increased 0.06 percent at 2nd month and 0.7 percent increase was found at 4th month. A sharp increase was observed at 10th month (from 0.35 to 0.50 percent). The value however increased to 0.7 percent at 14th month. The temperature of storage at 6°C/ 50% R.H also resulted in consistent showed continuous increase in NPN. The NPN content was found to be 0.62 percent at 16th month and 0.79 at 18th month, respectively.

The increase in NPN value was found higher at higher temperature of storage. At lower temperature of storage the increase in NPN also slowed down. This directly indicated that the storage temperature played an important role in NPN content of WPC. The increase in NPN content of WPC was primarily because of release of free amino acids and soluble peptides from the protein moieties, which could be slowed down by storing the product at lower temperatures.

DENATURATION OF WHEY PROTEINS

The denaturation rate of whey protein is related with both storage period and temperature of storage. It has been observed that the rate of denaturation
reaction was slower at lower storage temperature. The sharp increases in
denaturation of whey protein were observed at 4th month. Beyond 4th
month, although the increase in denaturation occurred consistently but at a
slower rate. It is also reported that heat stability decreases in skim milk
powder held at higher storage temperature i.e. at 28-32°C.

MICROBIOLOGICAL CHANGES IN WPC-70 DURING STORAGE

Enumerating SPC, Yeast and Mould, Coliform, Escherichia Coli and
Bacillus cereus assessed the microbiological quality of the fresh as well as
stored products. The count was determined every two month during storage
at 38°C/65% R.H, 24°C/60% R.H and 6°C/50% R.H temperature.

STANDARD PLATE COUNT

The storage temperature played vital role in multiplication rate of bacteria.
The bacteria continued to multiply up to 6th month and then receded rapidly
at 38°C/65% R.H. A similar, the trend of multiplication of bacteria was
found at 24°C/60% R.H and 6°C/50% R.H but up to 8th month and 10th
month, respectively, and then a decrease was observed. The growth of
bacteria occurred at slower rate at 6°C/50% R.H as compared to 24°C/60%
RH or 38°C/65% RH. Thus the lower temperature of storage inhibited the growth rate of bacteria.

YEAST AND MOULD COUNT.

These data indicated the yeast and mould did not multiply on storage at 38°C/65% RH. Slight increase in mould count was observed at 10th month, which may be because of increase in moisture content in the product at 6°C/50% R.H & 24°C/60% R.H storage, which favoured the growth of yeast slightly.

COLIFORM AND E-COLI

The count of Coliform and E. Coli was also determined during storage of WPC-70. These pathogens were found to be absent at O day and with progressive period of storage, no presence of these microorganisms was found irrespective of storage temperature/R.H. The results suggested that strict hygienic measures were adopted both during processing as well as storage of the product. Hence, the Coliform organisms remained absent throughout the storage period.

STORAGE RELATED SENSORY CHANGES

TASTE AND FLAVOUR

The taste profile of all the samples showed differently at different temperatures. At O day, the product found bland in taste up to 4, 10 and 12
month; milky taste found up to 8, 14 and 16 month and cheesy taste started at 10th, 16th and 18th month at temperature 38°C / 65% R.H, 24°C / 60% R.H. and 6°C/ 50% R.H, respectively. The scoring of flavour profile with respect to time suggested that when the WPC-70 approaches to <27 score, it was found unacceptable by the judges from acceptence point of view.

In the present study at ambient temperature (38°C / 65% R H) storage of WPC-70, the shelf life of the product was observed to be satisfactory up to more 8-month and. However, at 24°C / 60% R.H, the shelf life of the WPC-70 was considerably more that is 14 month, but less than 16 month. At refrigeration storage, the shelf life of product was found more than 14 month and less than 16 month. The storage studies indicated that the product stored at lower temperature was elicited longer shelf life (Flavour wise)

STORAGE RELATED COLOUR CHANGES

At refrigeration temperature (6°C/ 50% R.H) the colour was almost creamy white up to 14th and then changed to light yellowish cream and yellowish cream at 16th and 18th month, respectively. The product colour score was (average 13) i.e. 65 percent of the total score) and found still acceptable at 18th month.

4.5.4.3.7. The results of this investigation showed that colour changes at higher temperature (38°C / 65% R H) were very fast and shelf
life of the product can be terminated on the basis of colour at 10\textsuperscript{th} month. Storage at 24\degree C /60\% R.H, showed 14\textsuperscript{th} month termination of product shelf life. Degradation of colour was very slow at refrigeration temperature (6\degree C/ 50\% R.H). The product found acceptable even after termination period couldn't achieve even after 18\textsuperscript{th} month. The change in colour could be controlled by storing the product at lower temperature.

The results of this investigation showed that product had good appearance at refrigeration temperature (6\degree C/ 50\% R.H), followed by 24\degree C /60\% R.H and then at 38\degree C / 65\% R.H. The product was acceptable on the basis of appearance at lower temperature (6\degree C/ 50\% R.H) even at 18\textsuperscript{th} month. But based on flavour and colour score, the product showed less shelf life. At lower temperature the insoluble particles found were less as compared to storage at higher temperature. The opacity of reconstituted product was high at refrigeration temperature followed by 24\degree C /60\% R.H and the least at 38\degree C / 65\% R.H on their termination period of storage. This may be because of increase in the proportion denatured whey protein during storage, as mentioned in section 4.5.2.11.
**Best storage time period:**

During the storage the product (WPC-70) at different temperatures and relative humidities the following combinations have been found to be the best.

1. At temperature/ Relative Humidity: 38°C/65% RH ------ 8 months.
2. At temperature/ Relative Humidity: 24°C/60% RH ------- 14 months.
3. At temperature/ Relative Humidity: 6°C/50% RH ------- 16 months.

Thus the maximum shelf life of the product was achieved at refrigeration temperature is 6°C/50% RH

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