Indian Food Specialties Limited

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Indian Food Specialties Limited (IFS) introduced tools of food quality management in May 2000 in response to changing market conditions and poor profitability. Spoilage in the production process was very high and the company had incurred losses for three successive years starting from 1996-97. The company addressed quality concerns by introducing management tools such as quality control charts and process capability indices, and was considering implementation of a food safety system called Hazard Analysis and Critical Control Points (HACCP). The case describes the changing market conditions and the company's response to improving quality, and provides a learning exercise on quality control charts, process capability indices, and HACCP.

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On Friday, 19th May 2000, Mr Hemant Patil, 30, Quality Control Manager at the Indian Food Specialties (IPS) Limited, was analysing data on various quality parameters of pickle production. A week earlier, he had shared his concern over lack of uniform quality of pickles with floor supervisors and sought from them ways to improve it. IFS had incurred a cumulative loss for the last three years of Rs 4.87 crore. Although the loss was attributed to increased depreciation charges on account of the newly set up plant in Nasik, quality management had been one of the key concerns. Due to excessive spoilage in the production process, manufacturing expenses had been very high. In 1996-97, manufacturing expenses to sales ratio had reached a record high of 99 per cent. In later years, output was affected due to shortage of quality mangoes. Emphasizing quality, Hemant had read and explained to the supervisors the mission statement of the company which was conspicuously hung on the wall in front of his desk:

> *The mission of Indian Food Specialties Limited is to satisfy its customers' demand by supplying hygienic products to the customers' requirements and expectations both in national and international markets. The company is committed to produce and supply products to meet specifications by use of improved technology and comprehensive staff training and safe work conditions.*

For the past eight weeks till the middle of May 2000, production of mango pickle was in full swing due to a steady supply of raw mangoes. During that period, Hemant had collected data on two important mango pickle parameters: salt and acidity content. He had requested the floor supervisors to collate the data, prepare control charts to monitor the process, and assess process capability of pickle production (Box 1 for information on control charts and process capability). Floor supervisors had hoped that the end-product quality control charts would certainly help resolve the quality issue. The management of IFS also wanted to address a broader systemic issue of food safety and quality management. In fact, importers from the US were constantly inquiring about IFS putting in place the food safety management system - Hazard Analysis and Critical Control Points (HACCP)

(Box 2). The management wanted to make a beginning in this respect by applying the system to mango pickle production.

Company Background

The origin of Indian Food Specialties Limited dates to 1932. The company was started by Mr Yashwant Joshi. As a family-run business based in Mumbai, the company was engaged in import and export of dry fruits. Mr Joshi had a philosophical attitude towards food. In 1960, Mr Joshi talked about his food culture:

> *Food has grown in significance in all civilizations. It has grown from the gross physical appetite to a higher abode of aesthetic appreciation. Our business must evolve in that higher abode where food is a culture - a way in which men and women whet their appetites.*

In order to evolve and grow, Mr Joshi thought of product diversification. In the 60s, the company diversified into exports of processed foods under the brand names **OASIS** and **PALM TREE** to West Asia. Later, in 1992, the company was incorporated into a public limited company in the name of IFS Limited. The company's securities were listed on three stock exchanges in India: Mumbai, Pune, and Ahmedabad. The old name of the company was retained to hold on to its brand equity. Since then, the company had been producing a variety of value-added processed fruit and vegetable products that could be categorized as pickles, chutneys, ready-to-eat curries, and processed vegetables.

Box 1: Control Charts, Process Capability, and the Role of Statistical Techniques

Control charts are used for monitoring process performance, and measures of process capability are employed to assess suitability of a process for a particular product or operation. Both are derived from statistical principles that recognize that (a) process fluctuations are inevitable, and (b) process variability comprises of systematic variations due to controllable factors and random fluctuations due to uncontrollable factors. Random fluctuations or the noise factors are assumed to have a normal distribution with zero mean and process standard deviation (0) that is either known or estimated from sample observations.

In statistical process control (SPC), the objective is to monitor the process to ensure that variability is restricted to random fluctuations. Process variation beyond random fluctuation* calls for an investigation. This involves identifying factors responsible for deterioration in performance and taking corrective actions to restore the process to 'in control' state. Implementation of SPC first requires selection of parameters to monitor the process, designing control charts by selecting the sample size, sampling frequency, and determining appropriate upper and lower control limits (UCL and LCL). Operationally, process monitoring involves sampling at the pre-determined frequency and plotting the sample statistic on the control chart. While observations within the control limits indicate that the process is in control and performance is as expected, any observation outside the control limits would lead to the conclusion that the process is out of control and may require corrective action. X-bar control chart for process mean and R control chart for process variability are the most commonly used charts in many industrial applications. A number of secondary rules/guidelines has been developed in this context to facilitate interpretation of control chart results and to suggest corrective action.

While process control charts are operational in nature, process capability measures are tactical in nature and focus on the suitability of the process for the intended product. Product requirements are measured by the tolerance limits, and process capability is assessed by comparing random fluctuations of the process (as measured by the process standard deviation) with the tolerances limits. In this context, two measures, Process Capability (C_p) and Capability Index (C_{k}), are commonly used. While C_p measures the suitability of the process under the best process parameter settings, C_{pk} measures the capability under the current parameter settings. C_p is defined as the ratio of the difference between the tolerance limits to six times the process standard deviation; i.e., C = (UTL - LTL)/6a, where UTL and LTL are the upper and lower tolerance limits respectively and a is the process standard deviation. A C_p of 1.0 would imply that the process is capable of meeting the product specifications and would result in a yield of 99.73 per cent. A lower value of C_p would imply, likewise, an inferior process with higher levels of output outside the tolerance limits.

Box 2: HACCP System

Hazard Analysis and Critical Control Points (HACCP) is a food safety management system. The origin of HACCP (pronounced *hass-up)* is quite interesting. In the 1960s, the National Aeronautical and Space Application Centre (NASA) was looking for a way to guarantee totally safe food for astronauts on space flights. The prospect of astronauts suffering from food poisoning during a mission was unthinkable. They gave the task of producing zero-defect food to Pillsbury Corporation which responded by developing the HACCP system. Within two years of the first moon landing, Pillsbury Corporation started implementing HACCP concept in its agro-processing plants.

In HACCP, one systematically looks for potential risks and then identifies appropriate control and monitoring systems, concentrating on those deemed critical to the safety of the food product. The advantage in doing this is that control is transferred from end-product testing (i.e. testing for failure) to monitoring the design and manufacturing of agro-processed products (i.e. preventing failure). There will, however, always be a need for some end-product testing, particularly for on-going verification of the HACCP process. Among other things, preliminary steps in HACCP involve adhering to good manufacturing practices (GMPs) and preparing a flow-chart of the production process.

HACCP implementation requires adherence to the following seven principles: 1. Conducting hazard analysis; 2. Identifying critical control points (CCPs); 3. Setting critical limits for preventive measures for each CCP; 4. Establishing monitoring procedures; 5. Establishing corrective actions; 6. Establishing record keeping procedures; and, 7. Verification and validation of the system. While all principles are important, the crux of the system is in principles 1 and 2. A food safety hazard is a property that may cause food to be unsafe for human consumption. Hazard Analysis is very essential for identifying the potential hazards. A CCP is defined as a point, step or a procedure in the process flow-chart at which control can be applied and a food safety hazard can be prevented, eliminated or reduced to acceptable levels. A CCP decision tree (Exhibit 1) is used to assess each step in the flow-chart to determine whether it is a CCP.

By 2000, the company owned two processing units in Thane and a newly commissioned (1995) spices plant at Nasik, Maharashtra. The marketing office of the company was situated in Mumbai which looked after the domestic and international marketing of the products. The company had a turnover of Rs 40.15 crore in 1998-99, 90 per cent of which came from the export market. Exports to US, UK, Canada, Australia, and the West Asian nations contributed the most to its foreign exchange earnings (Table 1). The company was optimistic about the future and was ready to take all the necessary steps to get a firm foothold in the processed fruits and vegetables sector both in India and abroad.

For the last seven decades, under the leadership of Mr Yashwant Joshi, the company witnessed continuity and growth as it transformed itself from a proprietary concern into a public limited company. And, in these seven decades, it maintained its family business characteristic. Even by 2000, Mr Joshi was the Chairperson of the IFS Board of Directors. The company was managed by his sons, Suresh 59, and Anand, 57, in their capacity as Managing Director and Joint Managing Director respectively. Another son, Deepak, 49, was the Executive Director. The senior management was also dominated by the Joshis. Under the Presidentship of Mr Pramod S Joshi, there were two Vice Presidents, Mr Vineet S Joshi and Mr Girish A Joshi. The company had 250 employees on the payroll. Mr Hemant Patil, Quality Control Manager, reported to the General Manger, Mr B R Thakur. He, in turn, reported directly to the Vice Presidents of the company.

Table 1: Forex Earnings and Outgo

(Rs in Crore)

	1995-96	*1996-97*	*1997-98*	*1998-99*
Forex Earned	41.35	49.00	33.80	29.80
Forex Used	05.47	00.73	00.95	00.78

IFS's Brand Image

IFS had a wide spectrum of brands selling in different regions of the world. The company's brands were country-specific rather than product-specific, i.e., the products were sold under different brands in different countries. While pickles, pastes, and ready-to-eat foods in the UK and the US were sold under the brand name **YASH,** chutney and tamarind were sold in the UK under the brand name **OASIS.** In September 1997, IFS offered a franchise to a company in the UK to distribute its products in the ethnic Indian market and introduce its select products in the mainstream market. The company's distributors launched the product in the ethnic UK market under the brand name **YASH** and received very encouraging response. Despite stiff competition from the local manufacturers in the UK and high cost of entering the supermarkets, pickles, chutneys, and ready-to-eat meals sold under **YASH** brand achieved a turnover of Rs 8.76 crore in 1998-99 against Rs 5.90 crore in 1997-98. In 1999, plans were afoot to launch products in the mainstream market under the brand name **CLASSIC YASH.**

The company sold pickles and tamarind under the premium brand name **PALM TREE** in West Asia. The company also sold pickles, mango pulp, ready-to-eat vegetables, and spices in the West Asian countries under the brand name **SYLEE's,** the same brand name under which pickles and spices were sold in India. However, it was only in February 1998 that it could launch the **SYLEE's** brand of spices, pickles, and canned foods in the Saudi Arabian market. This brand had registered a turnover of Rs 8.72 crore and Rs 7.10 crore in 1998-99 and 1997-98 respectively for pickles and canned food items. The company was concentrating on strengthening the distribution and promotion of its products in North American market as well. Although it had not performed well in Australian and Far Eastern markets, efforts were on to improve performance in these markets. The brand-wise distribution of sales for 1999 is depicted in Exhibit 2. Finally, in its efforts to reach out to the world, the company had prepared an elegant homepage of its own. A hotlink proudly announced the following promotional quote:

Well-known food writer and gourmet, Leslie Forbes says, "When an Indian eats Western food today, he may, perhaps, be tasting his future. When Westerners eat Indian food, they are tasting their own past."

Company Performance and Changing Market Scenario

In 1991, in order to correct poor profit margins and ensure steady supply and good quality, the senior management of IFS had decided to shift focus to processing and manufacturing activity. The company increased its turnover from the manufacturing business compared to the trading business and made profits in 1995-96. However, it incurred losses since then. The loss in 1996-97 was mainly due to spoilage in the production process. In 1997-98, the mango crop was poor. There was a problem with supply of quality raw mangos, and raw mango prices leaped up by 200 per cent. Since raw mango was one of the key ingredients for various products of the company, both costs and quality were affected. The financial performance from 1995-96 to 1998-99 is presented in Exhibits 3 and 4. The company launched 13 new varieties of pickles in July 1999 to cater to the regional tastes in the domestic and international markets. With the addition of these new varieties, the company hoped to do better. Doing better in such circumstances meant adopting stricter safety and quality standards in the production process.

In fact, quality and safety aspects were becoming quite important for various reasons. In the past, catering to the ethnic Indian population abroad, IFS could afford to be somewhat lax in its quality. Increasingly, however, this segment of customers was getting quality conscious and demanding. The non-ethnic market was highly quality conscious, and conformity to quality specifications was critical. To compound the problem, safety and quality aspects had become extremely important with the signing of various trade agreements under the auspices of the World Trade Organization (WTO) in 1995. The agreement on Sanitary and Phytosanitary (SPS) measures had endorsed the food safety and quality guidelines of Codex Alimentarius Commission (Box 3). Though the Codex guidelines were not mandatory *de jure,* they had become mandatory *de facto* as WTO had endorsed them. An important component of the Codex guidelines was the compliance with the food safety management system, HACCP. Since 1995, officials from the United States Department of Agriculture (USDA) had started inquiring with the company about compliance with HACCP.

Food Quality and Safety Management

Getting ready for his meeting with Mr Thakur, Hemant examined the data collected during the past two months, and was wondering if the pickling operations and the plant were performing up to potential as regards quality. At the start of the mango season, he had initiated statistical process control procedures to monitor two important product parameters - salt and acidity content. While high levels of salt and acidity content could give a bad taste to the pickle, low levels could spoil the pickle. More importantly, branded product had to be uniform in terms of standard specifications for the quality attributes. Hemant had decided to monitor the two parameters through X-bar charts (for conformance to the desired level) and R charts (for consistency).

Box 3: Codex Alimentarius Commission

The Food and Agriculture Organization (FAO) and the World Health Organization (WHO) recognized the need for international standards to guide the world's growing food industry and to protect the health of consumers worldwide. Therefore, in 1962, these institutions jointly established Codex Alimentarius Commission. In Latin, *Codex* means law and *Alimentarious* means food. Hence, Codex Alimentarius means Food Law. The purpose of Codex was to guide and promote the elaboration and establishment of definitions, standards, and requirements for foods; to assist in their harmonization; and, in doing so, to facilitate international trade. While the code was developed in 1962, its general standards for labelling and standards for nutritional labelling were adopted in 1981 and 1985 respectively. In 1993, realizing the importance and usefulness of safety and quality control in the food manufacturing process, Codex recommended adoption of HACCP guidelines to food manufacturing processes. Taking the cue from Codex, US and European Union (EU) have already introduced HACCP in their food laws. Codex holds meetings on a regular basis to decide on standards for various food products. Hence, participation in these meetings is crucial if countries want their views and suggestions to get a serious hearing.

In the absence of reliable historical data, he had decided to construct control charts and determine the upper and lower control limits for the control charts using the sample data. (See Box 4 for mechanics of constructing control charts.) Data collected during the past eight weeks provided 57 daily samples, based on a sample size of seven. (The raw data collected during this period are provided in Exhibits 5 and 6.) Analysing the control charts for salt content (Charts 1 and 2), Hemant noticed that, on several days, the sample observations were outside the control limits and recognized that there was an immediate need for better control. However, he was not sure if this was due to workers not adhering to specified procedures or if it was due to the process itself. In the former case, better training and discipline could solve the problem. If the out of control situation was due to the process, further investigation and more elaborate intervention might be required.

Acidity level data were even more disconcerting (Exhibit 6). A first cut effort at construction of control charts resulted in nearly two-thirds of the observations falling outside the control limits. Hemant was not sure if the control charts were meaningful in this context and was wondering if the procedure had to be modified. He was also not sure if some more insights could be obtained from the individual observations in Exhibits 5 and 6.

More important, Hemant was concerned if the current process was capable of meeting the more stringent specifications required by the mainstream markets in the UK and US. For example, acidity levels of mango pickle had to be maintained between 1.5 and 1.7. Similarly, salt content had to be between 12.5 and 13.5. Being familiar with the efficient production processes (60 limits) in companies like Motorola, he was interested in determining the process capability of the pickling process. He was wondering if the current process was adequate or if there was a need for some expensive upgrading.

In parallel with the introduction of SPC methods, Hemant had initiated preliminary steps for adoption of HACCP in the plant. He had hired a consultant for advice on HACCP implementation. The consultant's report included a flow-chart for pickle production (Exhibit 7) and a decision tree for identifying critical control points (CCPs) for potential hazards (Exhibit 1). At each production step, three potential hazards were possible - microbial hazards such as bacteria, chemical hazards such as aflatoxins, and physical hazards such as flint stones, hair, and faecal matter. He shared these details with the supervisors. Besides the good manufacturing practices (GMPs) suggested by the HACCP consultant, they initiated several improvements in sanitary conditions in the plant and in personal hygiene of the workers. For example, the company constructed a washroom with a provision for anti-bacterial soap for the workers and commissioned a water purification and softening plant in the factory. It also placed easily noticeable instructions in English regarding hygienic practices at important locations in the plant. Hemant also instructed the supervisors to ensure that everyone washed their hands and legs and wore caps and gloves every time one entered the production floor. Further, he told them that no chewing and spitting of pan was allowed anywhere in the factory.

Thinking about his meeting with Mr Thakur on Monday, 22nd May 2000, Hemant saw a long weekend ahead to resolve the questions in his mind and to come up with specific recommendations and clearly defined priorities for improving the quality and safety aspects of mango pickle produced by IFS.

Box 4: X-bar and R Charts

A control chart with a specified sample size and sampling frequency is defined by the central line (CL) and upper and lower control limits (UCL and LCL). These parameters are a function of the underlying probability distribution of the sampling statistic (for example, sample mean X-bar and range R in the present case) and the desired confidence level for detecting shifts to out of control state. For commonly used control charts such as X-bar and R charts, factors to determine these parameters are tabulated and readily available. For example, Appendix 1 provides the factors required for computing the 3o* control limits (i.e., 99.73% confidence level) for X-bar and R charts with sample size up to 25. Basic data from k samples, each of size n, can then be used to define the control charts in the following manner.

i"1 observation of j^{th} sample, i = 1,2, ... n; j = 1,2,

X_{nj})/n

X.-bar = sample mean of j^{1h} sample = (X^ + X_{2j} + ...+

R. = Sample range of j"1 sample = Max (X.) - Min

Mean Range, R-bar = (R, + R_2 -K..-1-...+RJ/k A_2,

D_3 and D_4: Factors from Appendix 1

Parameters for X-bar Control Chart:

Grand Mean = (X, + X_2 + ...+ ... + X_k)/k

CL = Grand Mean

A_2 R-bar A R-bar

LCL = CL -UCL = CL +

Parameters for R Control Chart:

CL = R-bar LCL = D_3 R-bar UCL = D_4 R-bar

It may be noted that the above is based on the assumption that data are collected under controlled conditions while the process is in "in-control" state. Thus, observations that fall outside the control limits are treated as outliers and omitted from the computations. Once the control charts are set up, monitoring involves sampling at the pre-determined frequency and plotting the points on the control chart. Observations falling outside the control limits will trigger investigation to check the status of the process and, if necessary, corrective action to restore it to "in-control" state.

Chart 1: X-bar Chart for Salt Concentration

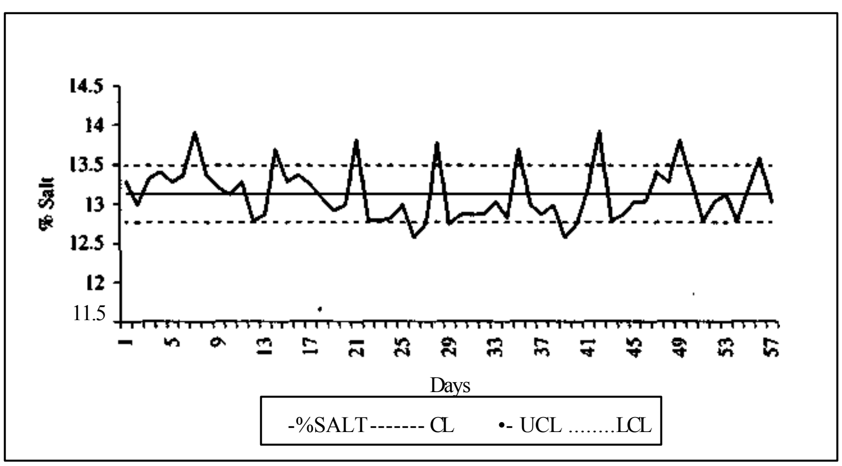


Chart 2: R-bar Chart for Salt Concentration

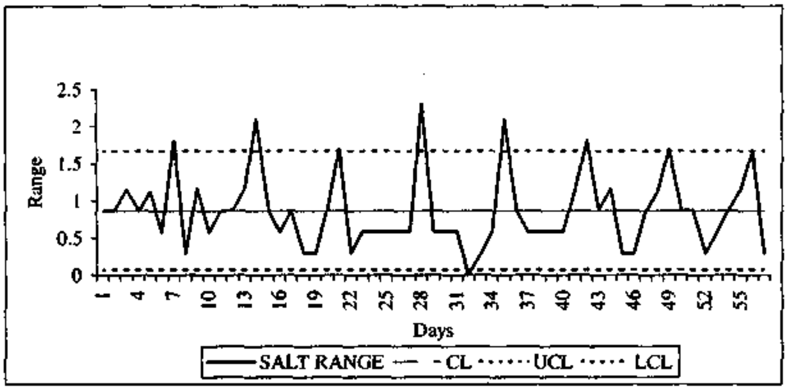
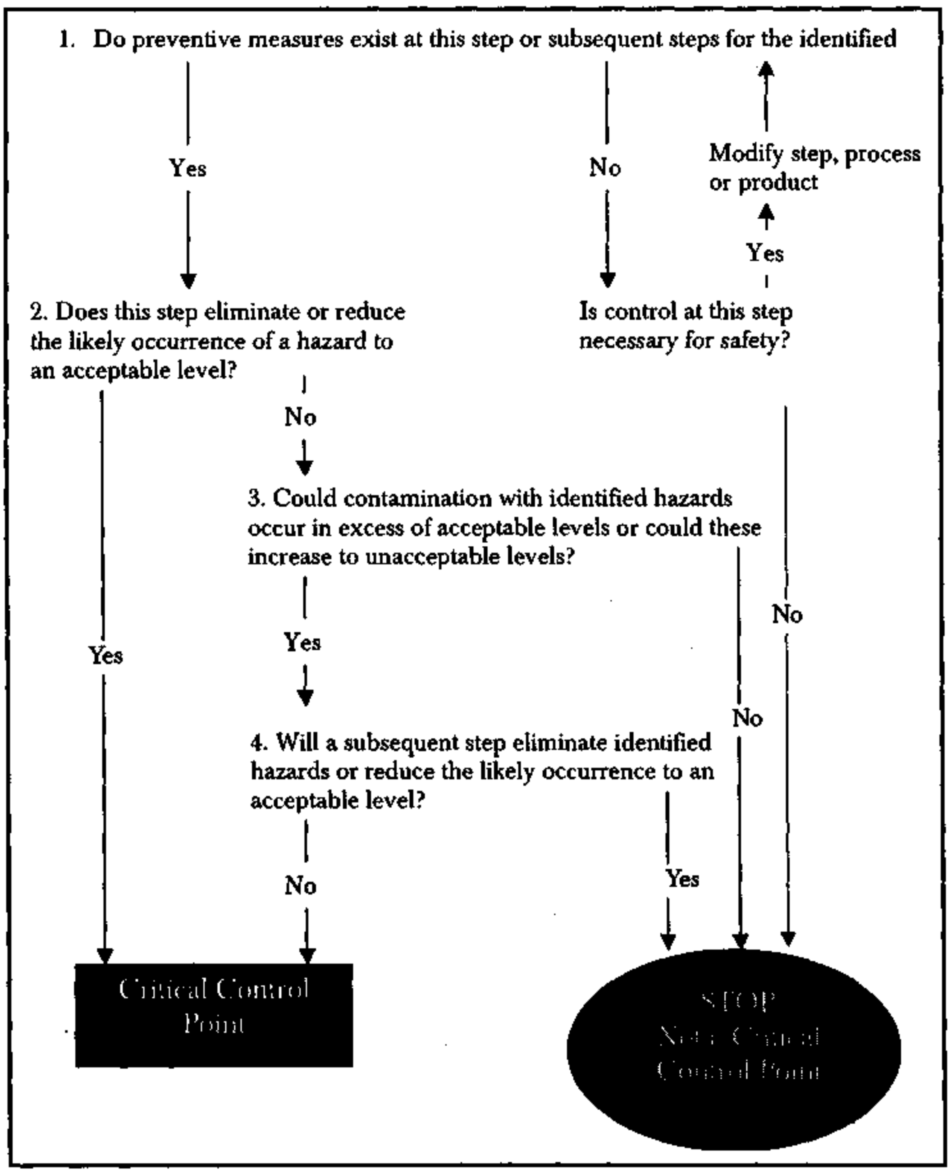


Exhibit 1: CCP Decision Tree*



*Adopted from Food and Drug Administration, USA.

Exhibit 2: Brand-wise Sales, 1998-99

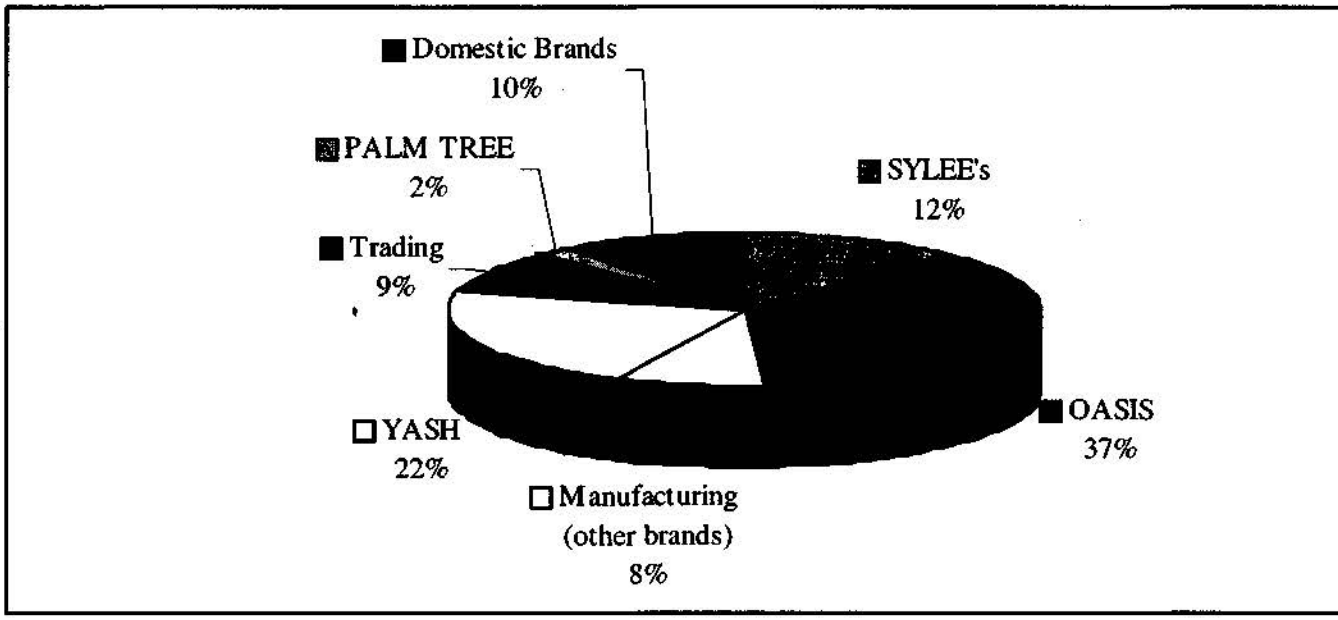


Exhibit 3: Profit and Loss Account for the Years 1995-96 to 1998-99

(Rs in Lakh)

	1995-96	*1996-97*	*1997-98*	*1998-99*
Income				
(a) Sales	5663.85	6065.87	4274.72	4014.88
(b) Other Income	80.24	94.65	31.54	36.83
(c) Increase/(Decrease) in Stock	-129.23	230.32	-136.34	81.47
TOTAL	**5614.86**	**6390.84**	**4169.92**	**4133.18**
Expenditure				
(a) Manufacturing and Other Expenses	5044.45	6018.89	3785.10	3789.22
(b) Financial Expenses	344.75	449.95	380.18	305.47
(c) Depreciation	40.29	83.85	97.32	100.76
(d) Misc. Expenditure Written-off	79.08	79.13	57.35	33.73
TOTAL	**5508.57**	**6631.82**	**4319.95**	**4229.18**
Profit/(Loss) Before Tax Less: Provision for Taxation	106.29	(240.98)	(50.03)	(96.00)
Profit/(Loss) After Tax	**106.29**	**(240.98)**	**(150.03)**	**(96.00)**
Balance Brought Forward	574.58	673.59	431.85	276.60
Balance Available for Appropriation	680.87	432.61	281.82	180.60
Less: Appropriations				
(a) Prior Period Adjustments (Net)	7.28	0.76	5.22	21.48
(b) Balance Carried to Balance Sheet	673.59	431.85	276.60	159.12
	680.87	**432.61**	**281.82**	**180.60**

Source: IFS Ltd., *Annual Reports.*

Exhibit 4: Balance Sheet for the Years 1995-96 to 1998-99

(Rs in Lakh)

	1995-96	*1996-97*	*1997-98*	*1998-99*
I Sources of Funds				
(1) Shareholder's Fund				
(a) Share Capital	1039.95	1040.17	1040.17	1040.17
(b) Reserves and Surplus	1637.38	1395.64	1240.40	1122.92
	2677.33	2435.81	2280.57	2163.09
(2) Loan Funds				
(a) Secured Loans	2075.45	1957.07	1927.2	1502.75
(b) Unsecured Loans	30.54	8.98	3.12	62.58
	2105.99	1966.05	1930.32	1565.33
TOTAL	**4783.32**	**4401.86**	**4210.89**	**3748.42**
II Application of Funds				
(1) Fixed Assets				
(a) Gross Block	981.32	2111.84	2151.59	2183.04
(b) Less: Depreciation	105.24	184.85	280.36	381.12
(c) Net Block	876.08	1926.99	1871.23	1801.92
(d) Capital Work in Progress	937.57		5.87	7.49
	1813.65	1926.99	1877.1	1809.41
(2) Investments	0.14	0.14	0.14	0.14
(3) Current Assets, Loans, Advances				
(a) Inventories	1643.16	1631.66	1550.68	1331.03
(b) Sundry Debtors	1280.52	801.34	687.75	668.07
(c) Cash and Bank Balance	129.68	63.09	23.16	72.41
(d) Loans and Advances	831.55	614.16	582.07	347.91
	3884.91	3110.25	2843.66	2419.42
Less:				
Current Liabilities and Provisions	981.78	657.31	466.81	497.13
(a) Liabilities	117.00	82.75	90.4	16.89
(b) Provisions	1098.78	740.06	557.21	514.02
	2786.13	2370.19	2286.46	1905.40
Net Current Asset				
(4) Misc. Expenditure (To the Extent Not Written-off or Adjusted)	183.40	104.54	47.19	13.47
TOTAL of (1) to (4)	**4783.32**	**4401.86**	**4210.89**	**3728.42**

Source: IFS Ltd., *Annual Reports.*

Exhibit 5: Observations for Salt in Mango Pickle*

Days(j)	*Per cent Salt*							*X-bar*	*,
1	13.16	13.74	13.45	13.16	13.45	13.16	12.87	13.28	0.87
2	12.57	12.87	13.16	12.87	13.45	12.87	13.16	12.99	0.88
3	13.45	13.16	12.87	13.16	12.87	13.74	14.03	13.33	1.16
4	13.45	14.03	13.45	13.16	13.16	13.16	13.45	13.41	0.87
5	13.16	12.87	14.00	13.45	13.16	12.87	13.45	13.28	1.13
6	13.74	13.16	13.16	13.16	13.45	13.45	13.45	13.37	0.58
7	13.16	14.68	13.87	14.57	14.27	14.00	12.87	13.92	1.81
8	13.45	13.45	13.16	13.16	13.45	13.45	13.45	13.37	0.29
9	12.57	13.45	13.16	13.16	13.74	13.16	13.16	13.20	1.17
10	12.87	13.16	13.16	13.45	13.16	13.16	12.87	13.12	0.58
11	13.45	13.16	13.74	13.45	12.87	12.87	13.45	13.28	0.87
12	12.87	13.16	13.16	12.28	12.57	12.57	12.87	12.78	0.88
13	12.57	12.87	13.16	13.16	13.45	12.28	12.57	12.87	1.17
14	14.67	14.00	13.74	13.45	14.00	12.57	13.45	13.70	2.10
15	12.57	13.45	13.45	13.45	13.45	13.16	13.45	13.28	0.88
16	13.45	13.16	13.16	13.16	13.74	13.45	13.45	13.37	0.58
17	12.87	13.16	13.45	13.16	13.74	13.45	12.87	13.24	0.87
18	12.87	13.16	13.16	13.16	12.87	13.16	13.16	13.08	0.29
19	12.87	12.87	12.87	12.87	12.87	13.16	12.87	12.91	0.29
20	12.57	13.16	12.87	12.57	13.45	13.16	13.16	12.99	0.88
21	12.87	13.16	14.00	14.57	14.57	13.74	13.74	13.81	1.70
22	12.87	12.87	12.87	12.57	12.87	12.87	12.57	12.78	0.30
23	12.57	12.57	12.87	12.87	13.16	12.57	12.87	12.78	0.59
24	12.57	13.16	12.87	12.87	12.57	12.87	12.87	12.83	0.59
25	12.87	13.16	13.16	13.16	12.57	13.16	12.87	12.99	0.59
26	12.57	12.57	12.57	12.57	12.28	12.87	12.57	12.57	0.59
27	12.28	12.87	12.57	12.87	12.87	12.87	12.87	12.74	0.59
28	14.88	12.87	13.74	13.74	12.57	14.57	14.00	13.77	2.31
29	12.57	13.16	12.87	12.57	12.57	12.57	12.87	12.74	0.59
30	12.57	12.87	12.87	13.16	13.16	12.87	12.57	12.87	0.59
31	12.87	12.57	12.87	12.87	13.16	12.87	12.87	12.87	0.59
32	12.87	12.87	12.87	12.87	12.87	12.87	12.87	12.87	0.00
33	12.87	12.87	13.16	13.16	12.87	13.16	13.16	13.04	0.29
34	12.87	13.16	12.87	12.87	12.87	12.57	12.57	12.83	0.59
35	14.67	14.00	13.74	13.45	14.00	12.57	13.45	13.70	2.10
36	12.87	13.16	12.55	12.87	12.87	13.16	13.45	12.99	0.90
37	12.57	12.87	12.87	13.16	13.16	12.87	12.57	12.87	0.59
38	12.87	13.16	13.16	13.16	12.57	13.16	12.87	12.99	0.59
39	12.57	12.57	12.57	12.57	12.28	12.87	12.57	12.57	0.59
40	12.28	12.87	12.57	12.87	12.87	12.87	12.87	12.74	0.59

Adapted and modified from the original data. *(Contd.)*

Days (j)	Per cent Salt							X.-bar	R
41	12.57	13.45	13.16	13.16	13.74	13.16	13.16	13.20	1.17
42	13.16	14.68	13.87	14.57	14.27	14.00	12.87	13.92	1.81
43	12.87	13.16	13.16	12.28	12.57	12.57	12.87	12.78	0.88
44	12.57	12.87	13.16	13.16	13.45	12.28	12.57	12.87	1.17
45	12.87	12.87	13.16	13.16	12.87	13.16	13.16	13.04	0.29
46	12.87	12.87	13.16	13.16	12.87	13.16	13.16	13.04	0.29
47	13.45	14.03	13.45	13.16	13.16	13.16	13.45	13.41	0.87
48	13.16	12.87	14.00	13.45	13.16	12.87	13.45	13.28	1.13
49	12.87	13.16	14.00	14.57	14.57	13.74	13.74	13.81	1.70
50	13.16	13.74	13.45	13.16	13.45	13.16	12.87	13.28	0.87
51	12.87	13.16	13.16	12.28	12.57	12.57	12.87	12.78	0.88
52	12.87	12.87	13.16	13.16	12.87	13.16	13.16	13.04	0.29
53	12.87	13.16	13.16	13.45	13.16	13.16	12.87	13.12	0.58
54	12.87	13.16	13.16	12.28	12.57	12.57	12.87	12.78	0.88
55	12.57	13.45	13.16	13.16	13.74	13.16	13.16	13.20	1.17
56	14.00	13.50	14.57	13.16	12.90	13.16	13.74	13.58	1.67
57	12.87	12.87	13.16	13.16	12.87	13.16	13.16	13.04	0.29

Parameters for X-bar Control Chart

CL = Grand Mean = 13.13
R-bar = 0.87
A_2=0.419
LCL =CL-A_2 R-bar =
UCL=CL+ A_2R-bar =12.76
13.50

Parameters for R-bar Control Chart

CL = R-bar = 0.87
D_3 = 0.076
D_4= 1.924
LCL = D_3 R-bar = 0.07
UCL = D_4R-bar=1.67

Exhibit 6: Observations for Acidity in Mango Pickle*

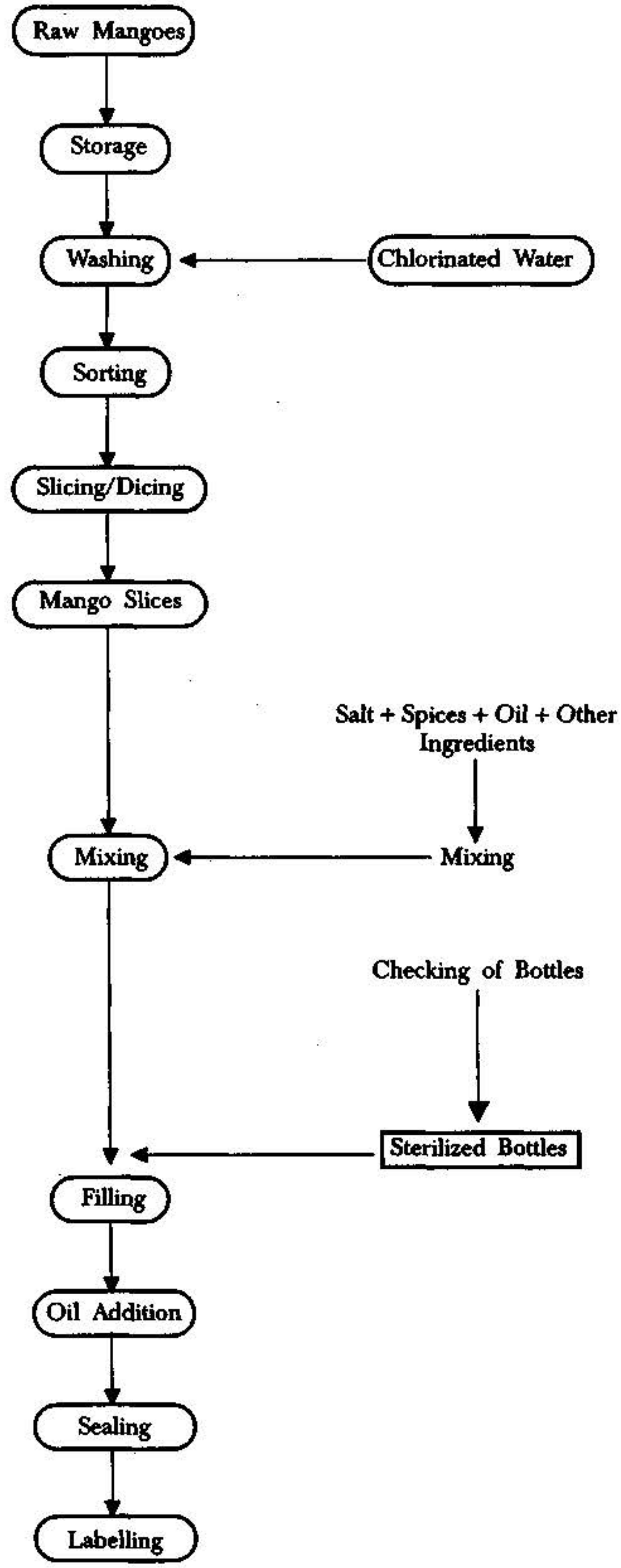
Days(j)	Per cent Acidity						
1	1.87	1.92	1.87	1.86	2.10	2.00	1.88
2	2.10	1.88	1.86	1.92	1.92	1.85	1.87
3	2.00	1.87	1.90	1.89	1.87	1.96	2.10
4	2.10	1.85	2.00	1.87	1.90	2.00	1.88
5	1.80	1.90	2.00	1.87	1.88	1.92	2.00
6	1.92	2.10	1.88	1.89	2.00	1.93	1.87
7	1.87	1.92	1.87	1.86	2.10	2.00	1.88
8	2.00	1.90	1.90	1.89	1.87	1.96	2.10
9	2.10	1.88	1.85	1.87	1.90	1.92	1.87
10	2.10	1.88	1.86	1.92	1.92	1.85	1.87
11	2.00	2.10	1.88	1.87	1.87	1.87	1.87
12	1.87	1.87	1.98	1.88	1.83	1.79	1.98
13	1.98	1.98	1.88	1.88	2.10	2.00	2.00
14	1.87	2.00	1.88	1.97	1.98	1.85	1.87
15	1.90	1.90	1.87	2.10	2.00	2.10	1.98

(Contd.)

Days (j)	Per cent Acidity					
16	1.62	1.60	L60	1.56	1.56	1.56	1.62
17	1.50	1.65	1.62	1.62	1.65	1.60	1.62
18	1.62	1.62	1.56	1.62	1.65	1.44	1.44
19	1.44	1.44	1.71	1.71	1.68	1.62	1.56
20	1.56	1.62	1.56	1.50	1.56	1.44	1.50
21	1.56	1.60	1.62	1.60	1.60	1.32	1.56
22	1.65	1.68	1.68	1.68	1.71	1.62	1.62
23	1.56	1.62	1.56	1.50	1.56	1.44	1.50
24	1.62	1.60	1.60	1.56	1.56	1.56	1.62
25	1.62	1.60	1.56	1.62	1.56	1.56	1.56
26	1.56	1.56	1.56	1.60	1.62	1.44	1.62
27	1.56	1.60	1.62	1.60	1.60	1.32	1.56
28	1.65	1.60	1.56	1.56	1.56	1.56	1.62
29	1.71	1.62	1.56	1.62	1.68	1.62	1.56
30	1.60	1.62	1.65	1.60	1.60	1.62	1.65
31	1.65	1.62	1.60	1.56	1.62	1.62	1.60
32	1.60	1.60	1.62	1.60	1.50	1.68	1.62
33	1.68	1.68	1.71	1.68	1.68	1.68	1.65
34	1.56	1.62	1.65	1.65	1.62	1.65	1.62
35	1.60	1.60	1.55	1.56	1.44	1.42	1.56
36	1.58	1.50	1.50	1.49	1.49	1.49	1.50
37	1.45	1.45	1.45	1.45	1.43	1.45	1.48
38	1.45	1.43	1.43	1.43	1.48	1.49	1.44
39	1.44	1.50	1.47	1.48	1.43	1.45	1.46
40	1.48	1.42	1.49	1.46	1.50	1.43	1.46
41	1.48	1.45	1.49	1.44	1.42	1.43	1.44
42	1.43	1.45	1.43	1.43	1.43	1.49	1.41
43	1.50	1.46	1.44	1.43	1.48	1.50	1.40
44	1.46	1.46	1.46	1.49	1.43	1.44	1.44
45	1.46	1.47	1.47	1.50	1.48	1.46	1.44
46	1.44	1.46	1.48	1.50	1.47	1.48	1.45
47	1.44	1.43	1.47	1.50	1.49	1.47	1.43
48	1.44	1.48	1.45	1.47	1.43	1.46	1.44
49	1.46	1.46	1.49	1.47	1.43	1.46	1.44
50	1.46	1.47	1.47	1.49	1.43	1.44	1.47
51	1.60	1.55	1.58	1.50	1.48	1.46	1.44
52	1.43	1.45	1.43	1.43	1.43	1.49	1.41
53	1.46	1.47	1.47	1.50	1.48	1.46	1.44
54	1.50	1.46	1.46	1.48	1.44	1.48	1.44
55	1.44	1.43	1.47	1.50	1.49	1.47	1.43
56	1.44	1.46	1.46	1.46	1.45	1.40	1.43
57	1.60	1.55	1.58	1.50	1.47	1.48	1.45

'Adapted and modified from the original data.

Exhibit 7: Flow Chart for Mango Pickle



Appendix 1: Control Chart Factors

Sample Size, n	Factors for X-bar Charts		Factors for R Charts		
	$d_2 = R/a$	$A_2 = 3/(d_2$"Jn)	$d_1 = a_R/a$	Z)J= $1-3d/d_2$	$D_4 = 1+3d/d_2$
2	1.128	1.881	0.853	0	3.269
3	1.693	1.023	0.888	0	2.574
4	2.059	0.729	0.880	0	2.282
5	2.326	0.577	0.864	0	2.114
6	2.534	0.483	0.848	0	2.004
7	2.704	0.419	0.833	0.076	1.924
8	2.847	0.373	0.820	0.136	1.864
9	2.970	0.337	0.808	0.184	1.816
10	3.078	0.308	0.797	0.223	1.777
11	3.173	0.285	0.787	0.256	1.744
12	3.258	0.266	0.779	0.283	1.717
13	3.336	0.249	0.770	0.308	1.692
14	3.407	0.235	0.763	0.328	1.672
15	3.472	0.223	0.756	0.347	1.653
16	3.532	0.212	0.750	0.363	1.637
17	3.588	0.203	0.744	0.378	1.622
18	3.640	0.194	0.739	0.391	1.609
19	3.689	0.187	0.734	0.403	1.597
20	3.735	0.180	0.729	0.414	1.586
21	3.778	0.173	0.724	0.425	1.575
22	3.819	0.167	0.720	0.434	1.566
23	3.858	0.162	0.716	0.443	1.557
24	3.895	0.157	0.712	0.452	1.548
25	3.931	0.153	0.708	0.460	1.540

Note: if l-3d,/d,<0, then D =0.

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