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Design, Development, And Evaluation Of Esomeprazole Gastroretentive Tablets Using Co-Processed Excipients

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Abstract: Esomeprazole is a proton pump inhibitor used in the treatment of Gastroesophageal Reflux Disease (GERD), peptic or duodenal ulcers, *Helicobacter pylori* infection, hyperchlorhydria, and in conjunction with other medications that have propensity to cause gastric ulcers. The biological half-life of esomeprazole is 1 to 1.5 hours with an oral bioavailability of 50-60%. It is known that gastroretentive drug delivery system (GRDDS) can increase gastric residence time and thus can improve the bioavailability. In this study, co-processed excipient (Xanthan-Guar gum prepared by solvent evaporation technique) in different ratios is used to reap the combined physico-chemical benefits of the individual excipients. Esomeprazole GRDDS tablets are thus developed to overcome the shortcomings of the drug and provide better therapeutic efficacy. The prepared tablets are evaluated for various quality control parameters such as diameter, thickness, hardness, friability, weight variation test, disintegration test, buoyancy, in vitro drug dissolution behavior, and drug release kinetics. It is observed that the formulation F5 containing 1:3 ratio of Xanthan and Guar Gum co-processed excipient has desirable properties of fastest floating lag time (4.42 $\pm$ 0.29 min) with a sustained drug release of up to 7 hours. This study proved that co-processed excipients can be used to provide hybrid benefits by providing additive effects on the overall drug performance in the body.

Keywords **– Gastroretentive drug delivery, Co-processed excipients, GERD, *H. pylori*, Esomeprazole.**

I. INTRODUCTION

Gastroretentive drug delivery systems (GRDDS) have unique advantages in the sense that they offer improved bioavailability to the drugs having poor absorption, they increase the gastric residence time, they provide a local effect, and lessen the adverse effects as the drug is localized to the gastric region only (BADONI *ET AL.*, 2012). Esomeprazole is chosen as an ideal candidate for this study due to its poor oral bioavailability (50-60%), low elimination half-life (1 to 1.5 hours), apart from its intended therapeutic action which is also said to be in the gastric region. GRDDS can overcome these disadvantages of the drug by promoting the gastric residence time (GRT), providing sustained action, and escalating the bioavailability (PRINDERRE *ET AL.*, 2011).

Use of co-processed excipients in the pharmaceutical industry has increased drastically in the recent years due to their versatility of offering the combined benefits of the excipients with single entity. These are prepared using spray drying, solvent evaporation, crystallization, melt extrusion or agglomeration techniques in which the excipients undergo sufficient stress such that the physicochemical properties of the excipients are modified and synergistic effect is obtained on the overall performance (Saha and Shahiwala, 2009). Past works on the co-processed excipients have revealed that usage of this technology not only provides decreased excipient usage but also overcomes the shortfalls of the drug with superior release characteristics (Wang *et al.*, 2015).

A thorough literature review revealed that there is very little work with Esomeprazole and co-processed excipients. The main aim of this research work is to develop Esomeprazole GRDDS tablets that can overcome the shortfalls of the drug and provide better therapeutic efficiency. The second objective is to evaluate the superiority of the co-processed excipients and compare their effect on individual polymers on the drug release. Esomeprazole is a BCS Class II drug (low solubility, and high permeability) and used in the management of gastroesophageal reflux disease (GERD), *H. pylori* infection, gastritis, hyperchlorhydria (Scott *et al.*, 2002). The pKa (4.78) of the drug favors its release in the gastric region and the development of GRDDS system provides extra mileage to the therapeutic effect of the drug (Spencer and Faulds, 2000).

II. MATERIALS

Esomeprazole is obtained as a gift sample from Sainor Laboratories, Hyderabad. Sodium bicarbonate, Citric acid, Polyvinyl pyrrolidone PVP K25, Xanthan Gum, Guar gum are procured from Molychem Pvt Ltd, Hyderabad. All the chemicals and excipients used in the research work are of analytical grade to ensure homogeneity and avoid any error due to source variation.

III. METHODOLOGY

3.1. Preformulation studies

Preformulation studies are carried out to ensure whether the physicochemical property of the Active Pharmaceutical Ingredient (API) is matching with the official monograph and to identify any deviations (Chaurasia, 2016).

3.1.1. Analytical studies

Esomeprazole can be estimated by using Gas chromatography (Reddy *et al.*, 2010), Liquid Chromatography-Mass Spectrophotometer (Cheng *et al.*, 2010), UV-Visible spectroscopy (Manoharan, 2019). In this study, Esomeprazole is estimated by using UV-visible spectroscopy as it is found to be effective, and economical with more reproducibility that suits the current work. The absorption maxima of esomeprazole in 0.1 N HCl is found to be 276 nm. 0.1 N HCl is used as a buffer to simulate the gastric environment where the drug is released. 100 mg of the drug is dissolved in 100 ml of 0.1N HCl. From this stock solution, 1-5 mL aliquots are transferred to 10 ml volumetric flasks to obtain 10-50 µg/mL solutions and the absorbance of each of the dilutions were determined by using double beam UV-visible spectrophotometer (Lab India UV-3200)

3.1.2. Drug-excipient compatibility studies using Fourier-Transform Infrared Spectroscopy (FTIR)

Drug Excipient incompatibility studies are carried out by FTIR spectroscopy (Shimadzu FT-IR 8400S) in the range of 400-4000 cm-1 with a resolution of 4 cm-1 using potassium bromide disc method (Reddy *et al.*, n.d.). The pure drug and excipient mixture (1:1 w/w) were stored at 40 ± 2^0C and 75 ± 5 % RH for 1 month. The powder sample is mixed thoroughly with potassium bromide for 3-5mins in a mortar and compressed into the disc. The pellets were placed in the sample chamber and the FTIR spectrum is analyzed for evidence of any interactions

3.2. Formulation of Esomeprazole floating tablets

3.2.1. Preparation of co-processed excipient

The floating tablets of Esomeprazole are prepared using a co-processed excipient of Xanthan gum and guar gum. Coprocessed excipient of xanthan and guar gum was prepared by using the solvent evaporation method (Bhatia *et al.*, 2022). Co-processed excipients for different formulations like (F1-F5) were prepared in the ratios of (1:1, 1:2, 2:1, 1:3, 3:1). Required quantities of xanthan and guar gum was weighed and dissolved in 10ml of petroleum ether. Then it was heated by using magnetic stirrer until all the solvent has been evaporated. Thus formed residue has to be dried in an oven and then dried sample was collected and the same procedure was carried out for all the formulations i.e, (F1-F5). The formulation F6 is prepared by taking the simple admixture of Xanthan and guar gum at a ratio of 1:1 to compare the differences between the individual excipient and coprocessed excipient.

3.2.2. Preparation of tablets

Floating tablets of esomeprazole were prepared by direct compression technique (Jaimini *et al.*, 2007). Required amounts of all ingredients like drug, coprocessed excipient of Xanthan and Guar gum, Sodium bicarbonate, citric acid, Microcrystalline cellulose, Magnesium Stearate and Talc were accurately weighed according to the quantities shown in Table 1 and passed through the sieve # 60. All the ingredients except magnesium stearate and talc were further mixed for additional 2-3min and various precompression parameters for the powder blend were carried out to determine the flow property of different formulations, and drug excipient compatibility studies were carried out. Then the powder blend was compressed using a tablet punching machine. Weights of all the tablets were kept constant in all formulations. Sodium bicarbonate and citric acid were used to produce the effervescence by the release of carbon dioxide, so the dosage form can easily float on within the stomach after tablet compression formulations were evaluated for the various compression parameters.

Table 1: Formulation of floating tablets of Esomeprazole

Sl. No.	Ingredients	Functional Category	Quantity (mg)/ 1 tablet					
			F1 (1:1)	F2 (1:2)	F3 (2:1)	F4 (1:3)	F5 (3:1)	F6 (Simple admixture)
1.	Esomeprazole	API	20	20	20	20	20	20
2.	Sodium bicarbonate	Effervescing agent	25	25	25	25	25	25
3.	Citric acid	Effervescing agent	12.5	12.5	12.5	12.5	12.5	12.5
4.	PVP K 25	Binding agent	12.5	12.5	12.5	12.5	12.5	12.5
5.	Xanthan & Guar gum	Co-processed excipient	20	20	20	20	20	20
6.	MCC	Diluent	150	150	150	150	150	150
7.	Talc	Glidant	5	5	5	5	5	5
8.	Magnesium stearate	Lubricant	5	5	5	5	5	5
9.	Total weight (mg)		250	250	250	250	250	250

3.3. Evaluation of pre-compression parameters

The powder blends of the drug and excipients are evaluated for various precompression parameters like Bulk density, tapped density, angle of repose, Carr's index, and Hausner's ratio to determine the flow properties and accordingly adjust the concentration of glidants and lubricants in the final formulation before compression (Gunda, 2015).

3.3.1. Bulk and Tapped density

5gm of powder blend of each formulation was accurately weighed and was transferred into a 100 ml measuring cylinder. Then the initial volume of the powder blend will be the bulk volume and it was repeated for three times and the mean of the values were taken and the final volume was taken as bulk volume and then the cylinder was tapped continuously for 100 tappings and recorded the final volume of powder, it will be the tapped volume *(Gunda, 2015)*. Same procedure was carried out for all the formulations. Then bulk and tapped density were calculated by using the given equation:

$$Bulk\ density\ = \frac{Weight\ of\ powder}{Bulk\ volume} \quad (3.1)$$

$$\text{Tapped}\ density\ = \frac{Weight\ of\ powder}{\text{Tapped}\ volume} \quad (3.2)$$

3.3.2. Angle of repose

Angle of repose is the angle between the slope of a powder pile and horizontal plane. It is determined by using static funnel method where a funnel was secured with its tip at a given height h, above graph paper that was placed on a flat horizontal surface. Granules were carefully poured through the funnel until the apex of the conical pile just touches the tip of the funnel. Thus, with r being the radius of the base of the conical pile angle, h being the height of the pile, angle of repose can be calculated using the equation 3.3. Angle of Repose value of less than 25 is considered as excellent flow property, 25 to 30 is regarded as good flow, 30 to 40 –moderate while angle of repose >40 is assumed as poor flow property.

$$\text{Tan}\ \theta\ = \frac{\text{Height of the powder pile (h)}}{\text{Radius of the powder pile (r)}} \quad (3.3)$$

3.3.3. Carr's index

It is also called Carr's compressibility index, is an indication of compressibility of a powder. It is calculated from the equation 3.4. Carr's index less than 16% is regarded as excellent flow while a value of 16-20% and value above 20% are regarded as good and poor flow respectively.

$$Carr's\ index\ = \frac{Tapped\ density - Bulk\ Density}{Bulk\ Density} * 100 \quad (3.4)$$

3.3.4. Hausner's ratio

It is the ratio of tapped density to untapped density. It is calculated by using the equation 3.5. A Hausner's ratio of less than 1.11 indicates excellent flow property.

$$\text{Hausner's ratio}\ = \frac{Tapped\ density}{Bulk\ Density} \quad (3.5)$$

3.4. Post compression studies

3.4.1 Diameter and thickness

Three tablets from each batch of formulation were collected and diameter of tablets was measured with the help of Vernier calipers and the average diameter was calculated. Similarly thickness of tablet (in mm) was also determined with the help of Vernier caliper *(Pare* et al., *2008)*. The measurements were taken in triplicate

3.4.2 Hardness

The hardness of the tablet is a official Test for the tablets as per IP and it was determined for all the formulations by using Monsanto type hardness testers (Padmavathy *et al.*, 2011). The hardness of the tablets can be measured by using monsanto hardness tester. This test was used to check whether the tablet has sufficient hardness to resist breaking during the normal handling and transportation. For each formulation, the hardness of three tablets was determined and the average is calculated. It is measured in kg/cm^2. A hardness of 4-6 kg/cm^2 is considered to be ideal.

3.4.3 Friability

It is carried out by using Roche Friabilator. 10 tablets were weighed initially ($W_{initial}$) and transferred into the friabilator operating at 25 rpm for 4 minutes. Then the tablets were weighed again after friabilation (W_{final}). The % friability was then calculated using the equation 3.6. The friability value should not be more than 1%.

$$\text{Friability} = \frac{(\text{Weight}_{initial}) - (\text{Weight}_{final})}{(\text{Weight}_{initial})} \quad (3.6)$$

3.4.4 Weight variation test

The weight variation test was carried out using 20 tablets by taking the individual weight and Average weight of 20 tablets. Weight variation is calculated by using the equation 3.7. The weight variation limit for a tablet weighing 250 mg or more is ± 5%.

$$\%\ Weight\ variation = \frac{Individual\ weight\ of\ the\ tablet}{Average\ weight\ of\ the\ 20\ tablets} * 100 \qquad (3.7)$$

3.4.5 Disintegration time

The disintegration time for floating tablets was determined by using USP disintegration test apparatus. Disintegration time for the prepared floating tablets can be determined by using USP disintegration apparatus (Jagdale *et al.*, 2009). The test involves usage of 6 glass tubes that are 3inches long, open at the top and 10 mesh screen at the bottom end. One tablet is placed in each tube and the basket rack is positioned in a 1-L beaker of water. Move the basket containing the tablets up and down through a distance of 5-6cm at a frequency of 28-32cycles per minute. Note down the time taken to disintegration of tablet and repeat the same procedure for all the formulations (F1-F5). The official limit of disintegration time is not more than 30 minute for uncoated tablets

3.4.6 Buoyancy studies

Buoyancy studies for the prepared floating tablets can be performed by using HCl. The prepared tablets from each of the formulations were placed in a beaker containing 100ml 0.1N HCl. Then the time taken for the tablet to emerge on the surface of the medium was noted and this will be the floating lag time. And the total duration of time by which tablet remained buoyant on the surface of the medium will be taken as the Total floating time *(Pare* et al., *2008)*. Same procedure is carried out for all the formulations

3.4.7 In vitro dissolution studies

The in vitro release of esomeprazole from the tablets was determined using a dissolution apparatus according to USP method II (paddle). This apparatus is placed in a water bath thermostatically maintained at 37^0C (+/-) 0.5^0C and stirred at a rate of 50 rpm. Sink conditions were maintained throughout the study. The dissolution medium is 900ml of 0.1N HCl pH 1.2. At pre-determined time intervals 5ml samples were withdrawn and replaced with fresh buffer solution *(Reddy* et al., *n.d.)*. Samples were filtered and analyzed using a UV-spectrophotometer at 276 nm. Released drug contents were determined from the calibration curve

3.4.8 Drug release kinetics

Mathematical models are used to evaluate the kinetics and mechanism of drug release from the tablets *(Nur and Zhang, 2000)*. The model that best fits the release data is selected based on the correlation coefficient (R) value in various models. The model with high 'R^2' value is considered as the best fit on the release data

3.4.8.1 Zero order release

The equation for zero order release is represented as

$$Qt = Q_0 + K_0 t \qquad (3.8)$$

Where: Qt = amount of drug released in time (t), Q_0 = initial amount of drug in the solution K_0 = Zero order release constant

3.4.8.2 First order release

The equation for zero order release is represented as

$$Log\ C = Log\ C_0 - \frac{K_t}{2.303} \qquad (3.8)$$

Where, C = amount of drug remaining unreleased at time (t)

C_0 = initial amount of drug in solution

K = first order rate constant

3.4.9 Statistical analysis

All the statistical analysis such as descriptive statistics, One-way ANOVA are carried out using JMP trial version 13.0. All the parametric tests are carried out at 5% level of significance

IV. RESULTS

4.1. Preformulation studies

Preformulation studies were carried out to identify and confirm the purity of the obtained sample of Esomeprazole. The results obtained were shown in the table 2

Table 2: Preformulation analysis of Esomeprazole

Sl. No.	Tests	Requirements	Results
1.	Description	White to off white, crystalline powder	Complies
2.	Solubility	Insoluble in water; sparingly soluble in alcohol freely soluble in chloroform	Complies
3.	Identification	by Melting Point Determination 169°C - 175°C	174^{0}C Complies
4.	Loss on drying	Not more than 0.5% t 105^{0}C for 4 hrs	0.37%
5.	Sulphated ash	Not more than 0.1%	Nil
6.	Assay	Esomeprazole sample contains not less than 90% and not more than 110% of the labeled claim.	99.84%

4.1.1. Analytical studies

UV spectrum of Esomeprazole in 1.2 pH HCl buffer solution shows that the drug has λ_{max} of 276 nm. The data for calibration curve of Esomeprazole in 1.2 pH HCl buffer solution is shown in table 3 and figure 1. The calibration curve was constructed over a concentration range of 2µg/ml to 10µg/ml and was found to be linear with r^2=0.990 and slope of 0.076 and intercept of 0.084

Table 3: Data for calibration curve of Esomeprazole

Concentration (µg/ml)	Absorbance			
	Trial –I	Trial –II	Trial –III	Average± S.D
2	0.157	0.162	0.164	0.161±0.003
4	0.235	0.253	0.244	0.244±0.009
6	0.312	0.298	0.324	0.311±0.013
8	0.378	0.347	0.386	0.370±0.020
10	0.469	0.479	0.486	0.478±0.008

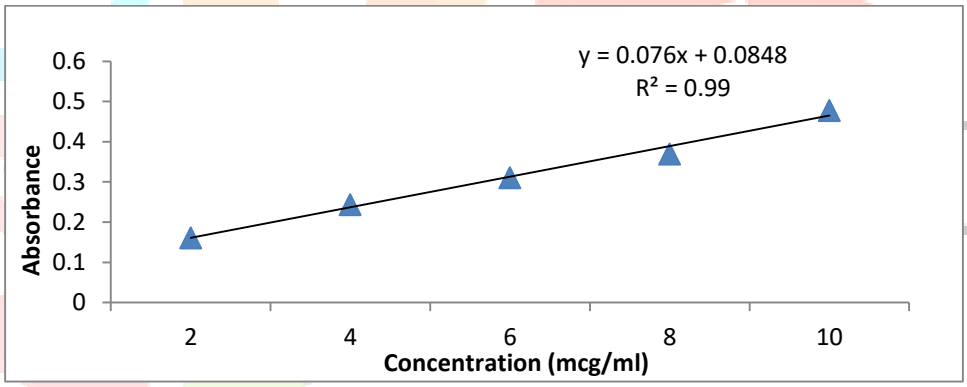


Fig 1: Calibration curve of Esomeprazole at 276 nm

4.1.2. Drug excipient studies using Fourier-Transform Infrared Spectroscopy (FTIR)

The results of drug excipient incompatibility by FTIR spectroscopy are shown in the fig 2 and table 4.

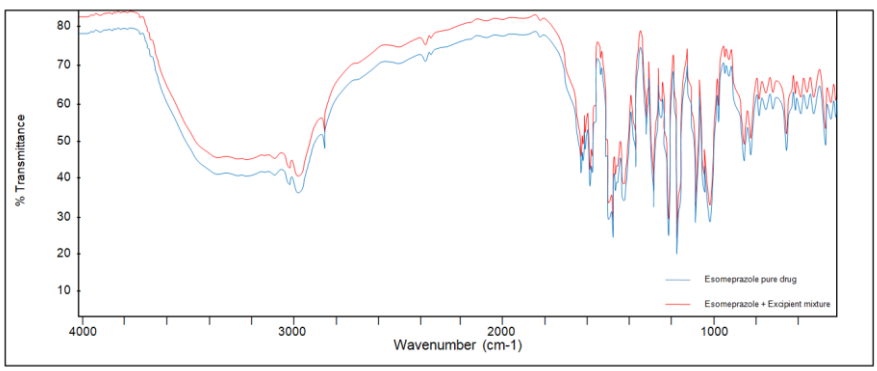


Figure 2: Drug-Excipient incompatibility studies by FTIR

Table 8: Drug Excipient incompatibility studies by FTIR

Sl. No.	Functional group	Pure drug (Absorption frequency cm^{-1})	Pure drug + Excipients mixture (Absorption frequency cm^{-1})
01	S=O stretching	1078	1081
02	C-O stretching	1230	1225
03	NH bending	1410	1412
04	C=N stretching	1620	1611
05	C=C-H asymmetric stretching	2880	2872

4.1.3 Solubility profile

The solubility profile of Esomeprazole is analyzed to determine buffers and the solvents required during formulation development. The results are shown in the table 9

Table 9: Solubility of Esomeprazole in Different Solvents

S.No.	Solvents	Solubility
1.	Distilled water	-
2.	6.8 pH Sorenson's buffer	-
3.	0.1 N HCl	+
4.	0.1 N NaOH	+
5.	Ethanol	++
6.	Methanol	++

Practically insoluble (-) slightly soluble (+) soluble (++)

4.2. Formulation of Esomeprazole floating tablets

The prepared tablets appear white in color, round in shape with smooth edges and no signs of chipping or capping or tearing. The obtained tablets are shown in the figure 3. The tablets are subjected to post-compression tests for determining the integrity of the tablets produced

Fig 3: Different formulations of Esomeprazole floating tablets prepared with co-processed excipients

4.3. Evaluation of precompression parameters

Before compressing into tablets, the precompression parameters are assessed to determine the extent of glidants and lubricants required so as to obtain uniform flow into the die cavity of the compression machine. The results of the pre-compression parameters are shown in the table 10

Table 10: Results of various precompression parameters

Formulations	Bulk density* (gm/cc)	Tapped density* (gm/cc)	Carr's index (%)	Hausner's ratio (%)	Angle of repose
F1	0.55±0.004	0.67±0.023	17.91	1.21	29±2.645
F2	0.54±0.012	0.66±0.005	18.18	1.22	30±1.439
F3	0.58±0.011	0.74±0.015	21.62	1.27	31±2.872
F4	0.59±0.006	0.71±0.017	16.90	1.20	28±0.225
F5	0.62±0.008	0.75±0.006	17.33	1.20	29±2.169
F6	0.64±0.015	0.78±0.005	17.94	1.21	27±1.752

* The values represent mean SD, n = 3

4.4. Post compression studies

The post compression properties of the gastro-retentive floating tablets of Esomeprazole like thickness, hardness and friability, for the formulations F1 to F6 were determined and the results are reported in table 11, 12

Table 11: Results for Thickness, Hardness, Friability

Formulations	Thickness* (mm)	Hardness** (Kg/cm2)	Friability (%)
F1	4.12±0.06	4.3 ±0.084	0.618±0.0002
F2	4.81±0.05	5.2 ±0.163	0.440±0.0002
F3	4.34±0.03	5.7 ±0.126	0.492±0.0002
F4	4.60±0.08	4.8 ±0.103	0.548±0.0004
F5	5.05±0.02	5.0 ±0.084	0.421±0.0003
F6	4.94±0.03	5.4 ±0.103	0.639±0.0002

* = Average of 3 readings SD, n=3. ** = Average of 3 readings SD, n=3.

Table 12: Results for weight variation, I*n vitro* disintegration time, FLT, TFT and drug content

Formulation	Weight variation (%)	*In-vitro* disintegration time (seconds)*	Floating Lag time (FLT) (min)	Total Floating Time (TFT) hrs	Drug content (%)
F1	2.29	34.33±0.57	11.32±0.81	24	98.68±0.678
F2	1.73	39.33±1.52	10.41±0.16	24	97.76±0.880
F3	0.87	45.00±1.00	6.21±0.63	24	98.13±0.660
F4	2.56	32.33±0.57	7.54±0.24	24	98.93±0.797
F5	1.01	15.36±1.52	4.42±0.29	24	99.18±0.354
F6	2.94	19.00±1.00	12.7±0.21	24	98.85±0.776

* = Average of 3 readings SD

Fig 4: Floating tablets of Esomeprazole in 0.1 N HCl

4.5 *In vitro* dissolution studies

In vitro drug release: The *in-vitro* drug release pattern of all the formulations F1 to F6 are given in the table 13 below and displayed in figure no. 5

Table 12: In vitro drug release studies

Sl. No.	Time (Hrs)	% Cumulative drug release					
		F1	F2	F3	F4	F5	F6
1	0	0	0	0	0	0	0
2	0.25	10.33	11.46	9.98	11.20	9.46	11.03
3	0.5	20.92	25.09	19.01	19.19	21.01	21.79
4	0.75	29.86	40.89	27.26	27.69	30.47	30.91
5	1	49.83	56.78	38.29	45.23	50.01	46.19
6	1.5	67.98	63.55	56.95	58.51	58.86	64.77
7	2	75.62	76.40	64.68	69.28	64.33	77.96
8	4	86.38	87.25	80.74	81.17	82.91	98.54
9	5	96.80	98.54	88.55	90.72	91.16	--
10	6	--	--	97.23	98.06	95.84	
11	7	--	--	--	--	99.14	

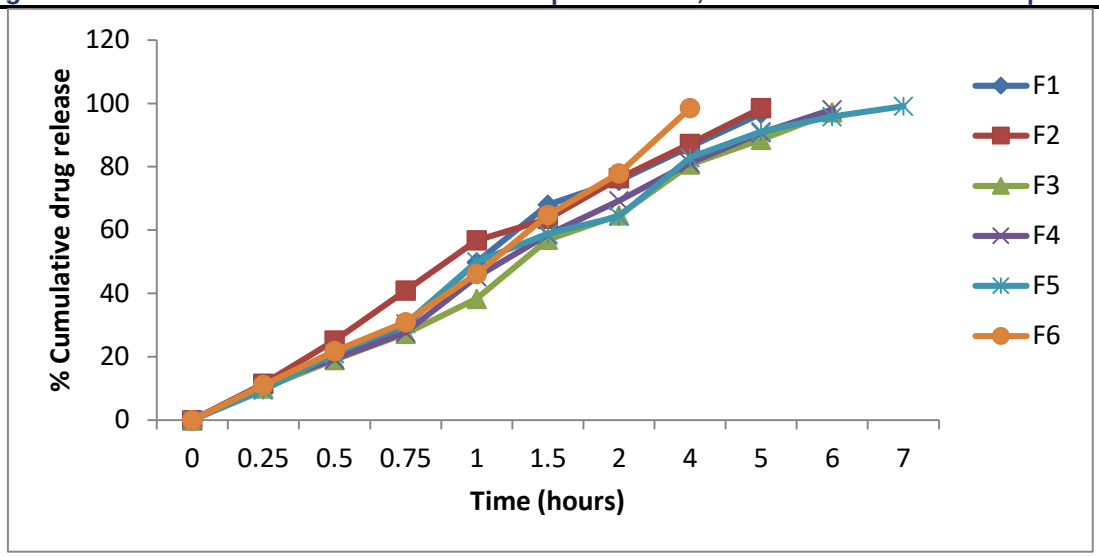


Fig 5: In vitro drug release of Esomeprazole gastroretentive floating tablets F1-F6

4.6 Drug release kinetics

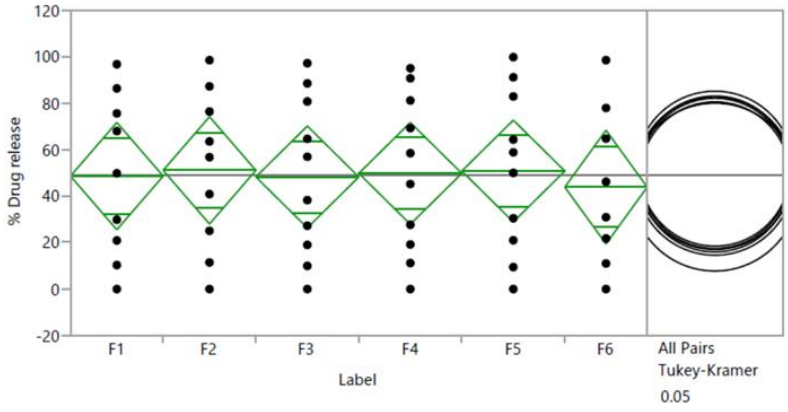
The data from the *in vitro* drug release is fitted into zero order and first order plots to determine the drug release kinetics. The results are shown in the table 13.

Table 13: Drug release kinetics of Formulations F1-F6

Formulations	Zero Order		First Order			Best fit model
	Slope (K)	R^2	Slope	K	R^2	
F1	12.71	**0.989**	-0.163	0.375	0.846	**Zero Order**
F2	12.44	**0.994**	-0.184	0.423	0.775	**Zero Order**
F3	12.03	**0.986**	-0.153	0.352	0.729	**Zero Order**
F4	12.01	**0.994**	-0.139	0.320	0.824	**Zero Order**
F5	12.44	**0.989**	-0.238	0.548	0.558	**Zero Order**
F6	13.91	**0.985**	-0.100	0.230	0.915	**Zero Order**

4.7 Statistical analysis

A one-way ANOVA test is performed to find out the difference between the treatment groups in terms of drug release at 5% confidence. The results are shown in the fig 6



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Label	5	293.006	58.60	0.0492	0.9984
Error	50	59496.096	1189.92		
C. Total	55	59789.102			

Fig 6: One-way ANOVA of drug release profiles of formulations F1-F6

V. DISCUSSION

Esomeprazole is a proton pump inhibitor used in the management of gastro-oesophageal reflux disease (GERD), erosive esophagitis, and H.pylori eradication to reduce the risk of duodenal ulcer recurrence. However, it is known to have **elimination half life of 1 to 1.5 hrs** and **low oral bioavailability (50-60%)** (Spencer and Faulds, 2000)**.** Formulation of such a drug requires a technique to increase the gastric residence time so as to improve the bioavailability of the drug. Formulating a proton pump inhibitor as gastroretentive system also provides intended action without systemic adverse effects. As esomeprazole is a BCS class II drug (low solubility and high permeability) and owing to its low bioavailability, the present study attempts to improve the bioavailability and dissolution of the drug using gastroretentive floating drug delivery system in order to improve the gastric residence time.

The drug was estimated by UV spectroscopy. Esomeprazole exhibited λ_{max} of 276 nm and its calibration curve in 1.2 pH HCl buffer was found to be linear over a concentration range of 2-10 µg/ml with r^2=0.990. The melting point of Esomeprazole was found to be 174ºC. It complies with standards and the solubility, assay, loss on drying, sulphated ash confirms the purity and authenticity of drug sample. Before choosing the excipients, a drug-excipient incompatibility study is carried out using FTIR spectroscopy which revealed that all the functional groups of the pure drug remained intact in the physical mixture thus paving the way for formulation of the gastroretentive floating drug delivery system with the intended excipients. Coprocessed excipient of xanthan and guar gum was prepared by using solvent evaporation method. Co-processed excipients for different formulations like (F1-F5) were prepared in the ratios of 1:1, 1:2, 2:1, 1:3, 3:1 respectively. The formulation F6 is prepared by taking the admixture of Xanthan and guar gum at a ratio of 1:1 to compare the differences between the individual excipient and coprocessed excipient (Wang *et al.*, 2015).

Precompression studies indicated that the drug has fair to good flow property, necessitating the need for addition of glidants and lubricants to have adequate flow property. The pre compressional parameters like flow properties of liquisolid mixtures were found to be satisfactory as indicated by Carr's index (16.90-21.62 %), Hausner's ratio (1.20-1.27%) and angle of repose (28.0-31.0). Direct compression method is used to prepare the gastroretentive floating tablets. Average hardness of the tablet ranges from 4.12 to 5.05 kg/cm^2 which was within the limits. Friability values are in the range of 0.44% to 0.639%. This indicates that acceptable resistance is shown by the tablets to withstand handling. Weight variation was found to be in the range of 0.87% to 2.94% for all the formulations, indicating that all formulations passed the test (Chaurasia, 2016).

Disintegration time was found to be in the range of 34.33 ± 0.57 sec to 45.0 ± 1.00 sec. Faster disintegration time indicate rapid release rates. The floating lag time of the formulations is in the range of 24 min to 60 mins. Drug dissolution studies indicated that the formulations containing higher proportion of xanthan gum have a better controlled drug release when compared to guar gum. The order of drug release from the formulations is in the order of F5>F3>F4>F2>F1>F6. The formulations F5, F3 has higher proportion of xanthan gum and lower proportion of guar gum (3:1 and 2:1 respectively) indicating that xanthan gum has a more sustained action on the drug release.

Curve fitting analysis revealed that the drug release from the formulations followed zero order kinetics as evident from the higher r^2 values. This is consistent with theoretical assumptions that sustained release dosage forms follow zero order (concentration independent) kinetics. Statistical analysis is carried out to determine the differences in the drug release pattern from the formulations. It can be seen from the One-way ANOVA analysis that there is no significant difference ($p>0.05$) in drug release between the formulations indicating that Xanthan gum and Guar gum are good either as coprocessed excipients or when used alone. However, the drug release from F6 that contains compound mixture of Xanthan gum and Guar gum is significantly lower than all the other formulations (F1-F5) which contains the coprocessed excipient indicating its superiority. Basing on the post-compression parameters, drug release, and floating lag time **F5 containing 3:1 ratio of Xanthan gum and guar gum is chosen as the best formulation**.

VI. CONCLUSION

Formulation F5 which contained 1:3 ratio of Xanthan gum and guar gum as co-processed excipient had a better floating time among the six formulae at 4.42±0.29 min, with consistent drug release for a period of up to 7 hours. Thus, formulation F5 is chosen as the best formulation among others. From this study it can be concluded that co-processed excipients can breathe new life to the existing excipients combing the desirable properties to achieve a hybrid excipient that possesses the individual advantages of both the excipients and alter the therapeutic performance of the drugs

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Unconventional stationary phases: Nanomaterials, nanoparticles and the future of liquid chromatography

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Abstract

This review article discusses the impact of nanostructured stationary phases on liquid chromatography and separation science. These materials have revolutionized chromatography by enabling unprecedented levels of sensitivity, resolution, and applicability. Nanoporous silica, graphenic, monolithic, and nanoparticle-based phases continue to push the boundaries of biomolecular analysis, molecular diagnostics, and traceability testing. Nanostructured phases have made early detection of diseases, comprehensive profiling of proteomes, enhanced food origin traceability, and sensitive environmental monitoring possible. They facilitate isolation and analysis of biomacromolecules, extracellular vesicles, viruses, and trace constituents with high specificity and sensitivity even from minimal sample volumes. Furthermore, nanostructured phases are enabling integrated techniques, sensing capabilities, and responsive microdomains for advanced detection, purification, and separation of analytes. Continued progress in nanomaterial design, surface engineering, and micro-nanofabrication will lead to more sophisticated nano-LC approaches with translation across healthcare, food safety, materials analysis, and global sustainability. The review concludes that nanostructured stationary phases represent a pivotal frontier in chromatography and analytical sciences with tremendous potential to transform molecular diagnosis, precision medicine, origin traceability, and monitoring of health, food, and environment quality. Nano-LC promises to make comprehensive and minimally invasive molecular-level understanding more feasible, accessible, and impactful. These materials are an enabling technology with immense and far-reaching possibilities that will likely shape developments in analytical sciences and their use for years to come.

Keywords: Liquid Chromatography; Nanoparticles; Silica Gel; Proteomics; Molecular diagnostics

1. Introduction

Liquid chromatography (LC) relies on stationary phases with tailored characteristics for effective separation of analytes. Silica has traditionally been the most popular stationary phase material, but various inorganic and organic stationary phases have since been developed to suit diverse analyses [1].

In recent years, nanomaterials have emerged as promising candidates for stationary phases, with their unique properties enabling new levels of performance. Nanoporous silica, zirconia, titania, graphene and other nanomaterials are able to provide ultra-high surface areas, nanoscale confinement effects and facile surface modifications for superior sensitivity, resolution and applicability [2].

Nanoporous silica phases contain a network of nanopores that drastically increase solute retention and saturation capacity. Nanoparticle-coated and monolithic nanomaterials exhibit versatile and optimized characteristics based on their composition, nanostructuring and degree of hydrophobicity/hydrophilicity. Nanoporous graphene phases offer

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an exceptional combination of high surface area, conductivity and biocompatibility for emerging areas like proteomics, metabolomics and biomaterial sensing [3, 4].

Nanomaterial stationary phases are rapidly advancing liquid chromatography to achieve faster, more sensitive and high-resolution separations even for highly complex mixtures. From biosamples to trace contaminants, these innovative "nanophases" are enabling new possibilities in analysis, discovery and precision medicine. Continued progress in nanomaterial design, surface tailoring and integrated applications will ensure that nanoscale confinement and tailored nanoenvironments remain central to future breakthroughs in LC methodology and applications [5].

Nanomaterial stationary phases represent the frontier of liquid chromatography methodology, with nanoscale porosity, nanoparticles and advanced engineering of phase characteristics set to transform separation science and its use in fields like biomedicine, food/environment testing, and materials science. This overview explores the current and emerging possibilities of these transformative stationary phases.

2. Types of Nanoporous stationary phases

Nanoporous stationary phases exploit nanoscale pore structures to maximize surface area and achieve enhanced sensitivity, solute capacity and chromatographic performance. Porous silica, zirconia, activated carbon and graphenic materials have been employed for nanostructuring the pores in these phases [6]. Different kinds of nanostructured stationary phases and their characteristics and applications are shown in Table 1.

Table 1 Different types of nanostructured stationary phases currently used in liquid chromatography

SN.	Nanostructured Stationary Phase	Characteristics	Applications
1	Nanoporous Silica	Porous structure with high surface area	Separation of small molecules, biomolecules, and peptides
2	Graphene Oxide	High adsorption capacity and selectivity	Separation of aromatic compounds, peptides, and proteins
3	Monolithic	Continuous porous structure with high permeability	Separation of small molecules, peptides, and proteins
4	Nanoparticle-based	High surface area and selectivity	Separation of peptides, proteins, and small molecules
5	Core-shell	Unique surface chemistry and high selectivity	Separation of small molecules, peptides, and proteins

2.1. Silica-based nanoporous hybrid phases

Silica-based nanoporous hybrid phases contain a network of silica Nanopores that provide up to 1000 m^2/g surface area, enabling increased solute retention and saturation. The porous framework also allows for facile mass transfer, resulting in improved sensitivity and less band broadening [7].

2.2. Nanoporous zirconia and titania phases

Nanoporous zirconia and titania phases utilize the high surface area (up to 500 m^2/g) and hydrophilic-hydrophobic switchability of these nanomaterials for enhanced separations of polar and nonpolar compounds. These ceramic nanoporous phases are highly stable and able to withstand harsh mobile phase conditions [8].

2.3. Graphenic Nanoporous phases

Graphenic nanoporous phases, like porous graphene oxide, possess an ultrahigh surface area of up to 2600 m^2/g and exceptional adsorption capacity. They are able to efficiently retain and release biomolecules, facilitating sensitive proteomic analysis and other biomedical applications. Three-dimensional networking of nanopores in these phases provides numerous isolated nano-domains for selective separation of closely related compounds [9]. The unique features of the various nano-based stationary phases are shown in Figure 1.

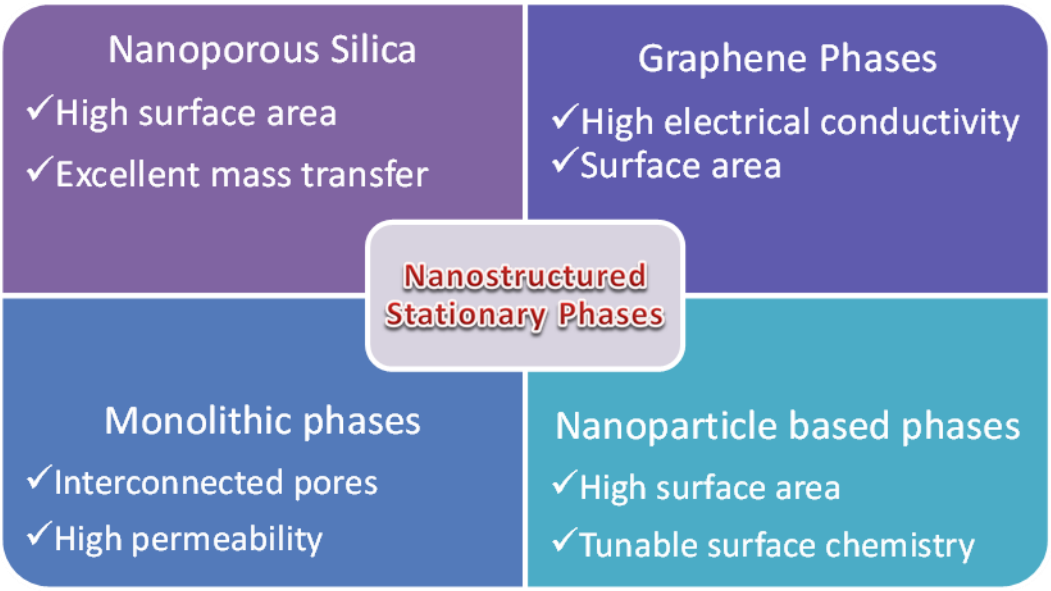

Figure 1 Various nanostructured stationary phases

The array of pore sizes, surface chemistries and structural features possible with nanomaterials enables highly tunable stationary phases with optimized performance for different applications. Nanoporous phases continue to push the boundaries of sensitivity, speed, resolution and applicability of liquid chromatography separations [10].

With their ultra-large surface areas, nanoscale confinement effects and facile surface modification, nanoporous stationary phases represent an exciting frontier in separation science with tremendous potential for biomolecular analysis, precision medicine and other advanced applications. Continued innovation in nanostructuring porous silica, graphenic and other nanomaterials will lead to high-impact developments in nano-LC in the coming years [11].

2.4. Monolithic phases

Three-dimensional nanoporous graphenic materials exhibit an unparalleled combination of high surface area, electrical conductivity and biocompatibility that is ideal for sensing, separation and analysis of biomolecules. Porous graphene oxide (GO) and reduced graphene oxide (rGO) containing a 3D network of nanopores possess specific surface areas of up to 2600 m^2/g, much larger than conventional silica phases [12]. The sensitivity and resolution of nanostructured stationary phases when compared to conventional stationary phases are shown in Figure 2.

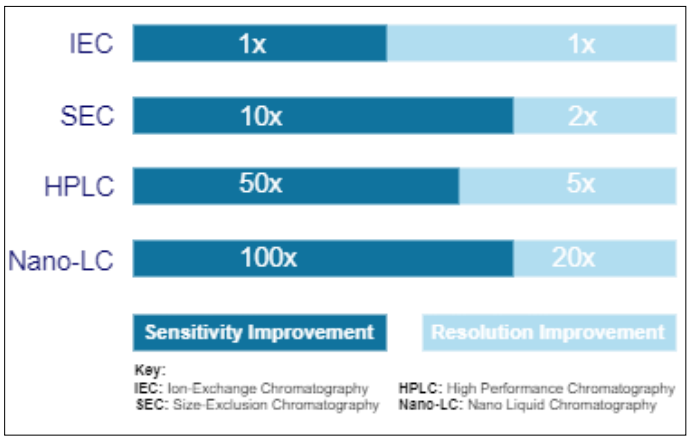

Figure 2 A graph showing the sensitivity and resolution improvements achieved using nano-LC approaches in comparison to traditional liquid chromatography techniques

The huge surface area of nanoporous graphene phases enables exceptional retention of peptides, proteins and other bio-macromolecules for enhanced sensitivity in detection and quantification of these analytes. At the same time, the porous structure allows for facile diffusion of small molecules, resulting in high efficiency and sensitive detection even of trace components. This enables highly sensitive proteomic analyses, early diagnosis of diseases from low-level biomarkers and monitoring of drug responses [13]. The sensitivity, resolution, and applicability of traditional liquid chromatography techniques are compared in Table 2.

Table 2 Sensitivity, resolution, and applicability of traditional liquid chromatography techniques with those of nano-LC approaches

Sl.No.	Technique	Sensitivity (ng)	Resolution (Rs)
01	High-Performance Liquid Chromatography (HPLC)	100	1.5
02	Ultra-High-Performance Liquid Chromatography (UHPLC)	10	2.5
03	Nano-Liquid Chromatography (nano-LC)	1	5

The conductivity and electro-active nature of nanoporous graphenic phases also provides possibilities for direct electrochemical sensing, biosensing, and sensor arrays with high sensitivity, selectivity and real-time measurement ability. These phases can bind biological molecules, enzymes or antibodies on their surface to fabricate selective and responsive biosensors for detection of health-related analytes like glucose, cholesterol, prostate specific antigen, etc. They also show potential as electrochemical electrodes for detection of neurotransmitters, drugs of abuse and other biomolecules [17].

Emerging areas of application include environmental monitoring of contaminants, food testing for additives/pathogens, and analysis of exosomes for noninvasive detection of diseases. Nanoporous graphenic phases continue to enable new sensing opportunities and promote the development of minimally invasive "liquid biopsy" techniques based on detection of circulating biomolecules [18].

With enormous surface areas, superior biocompatibility and intrinsic conductivity, 3D nanoporous graphene promises to revolutionize the field of biosensing, biodetection and molecular diagnostics. While still developing, these innovative phases could make comprehensive health monitoring, precision medicine and prevention of pandemics more feasible through sensitive and controllable analysis of biomolecules. Nanoporous graphenic separators and sensors will likely transform healthcare and global well-being in the years to come [19].

2.5. Other nanoparticle based stationary phases used in liquid chromatography

Nanoparticles of metals (gold, silver), metal oxides (titania, zirconia), magnetic (iron oxide) and semiconductor materials (quantum dots) have been employed as modifiers to tailor the characteristics of stationary phases for improved separations and sensing [20, 21]. These nanoparticles exhibit properties like catalysis, magnetism, fluorescence that can enhance selectivity, sensitivity and resolution of analyses.

Gold nanoparticles (AuNPs) provide catalytic sites to facilitate chemical conversion or sensing of reactive analytes on the stationary phase surface. AuNP-modified phases show potential for detection of biomolecules involved in diseases, pollutants in environment testing, and trace contamination in food analysis with high sensitivity. Silver nanoparticles exhibit antibacterial activity and have been coupled to stationary phases for rapid removal of pathogens [22].

Magnetic iron oxide nanoparticles allow for magnetic separation, pre-concentration and detection of analytes using magnetic fields. Magnetic stationary phases enable highly sensitive detection of biomolecules, nucleic acids, hormones and drugs in complex matrices like blood, serum, urine, etc. They also provide possibilities of on-line extraction and cleanup using magnetic trapping to achieve superior selectivity and detection limits [23].

Semiconductor quantum dots possess unique optical properties that can be tuned based on their size and composition for development of phases with specific sensing capabilities. Quantum dot-modified stationary phases enable highly sensitive and selective fluorometric/colorimetric detection of pharmaceuticals, toxins, food additives, pathogens, etc. Multiplexing the detection of various analytes is feasible using a combination of quantum dots with different emission wavelengths [24].

Nanoparticle-templated stationary phases have been created by self-assembly or layer-by-layer deposition of nanoparticles on phase surfaces to achieve sophisticated characteristics, responsive microdomains, and high surface area with efficient mass transfer. These versatile phases show promise for applications like drug screening, proteomic profiling, metabolomic analyses and biomedical diagnostics with enhanced resolution and detection of analyte subsets [25].

Continued advancement in engineering nanoparticles with improved biocompatibility, catalytic activity, magnetic properties and sensing functionalities will lead to greater sophistication of nanoparticle-based stationary phases [26]. Their ability to enable highly optimized, responsive and multifaceted detection and separation will likely drive progress in molecular detection, precision medicine and health monitoring through minimally invasive means [27]. Nanoparticle modifiers thus represent crucial enabling technology for next-generation bioanalysis and diagnostics [28].

3. Applications

Nanostructured stationary phases have revolutionized proteomics, enabling discovery of biomarkers, monitoring of disease progression, and development of precision medicine. Nanoporous silica and graphenic phases can isolate, concentrate and detect proteomic analytes with ultrahigh sensitivity from minimally invasive biosamples like serum, plasma, urine, etc. This has made early detection of cancers, monitoring of treatment efficacy, and diagnosis/prognosis of mental health conditions possible using low-abundance protein biomarkers [29].

Nano-LC is crucial for comprehensive profiling of the plasma proteome to identify novel disease biomarkers and gain insights into pathophysiological mechanisms. It facilitates detection of biomarkers even at attomolar concentration levels from limited sample volumes. Sensitive proteomic analyses now enable monitoring of disease relapse, response to therapy, and toxicity due to drug treatments. Nanoporous stationary phases thus promote progress in personalized and precision medicine through proteomic applications [30].

Nanophases are also enabling enhanced origin traceability, quality/authenticity testing and detection of food adulterants. They can isolate, retain and detect subtle compositional differences in food products based on origin, variety, processing technique, additive use, etc [31]. This helps ensure food safety, protect geographical indicators, and combat food fraud. Nano-LC based approaches using nanoporous silica or monolithic stationary phases have achieved ppb-level detection of contaminants, adulterants and trace constituents in food, beverages, herbs and spices [32].

Emerging applications include isolation of extracellular vesicles (exosomes), virus particles and other biocolloids for analysis, detection or other applications. Nanostructured stationary phases can effectively concentrate, isolate and purify these nanoscale structures from complex mixtures. They also promote improved final elution and recovery of intact vesicles/virus particles enabling their use in drug delivery, regenerative medicine, diagnostics, and vaccine development. The comparative advantages and disadvantages of nanostructured stationary phases with different types of analytes are shown in Table 3.

Table 3 Comparative advantages and disadvantages of nanostructured stationary phases with different types of analytes

Sl.No.	Analyte Type	Advantages	Disadvantages
01	Biomacromolecules [25]	✓High separation efficiency ✓High resolution ✓Improved sensitivity ✓Reduced sample size required	×Limited availability of stationary phases ×Cost ×Complexity of synthesis ×Potential degradation of stationary phase
02	Extracellular Vesicles [25]	✓Improved selectivity ✓Enhanced detection sensitivity ✓Reduced sample size required	×Limited availability of stationary phases ×Complexity of synthesis ×Potential degradation of stationary phase

03	Viruses [25]	✓High separation efficiency ✓High resolution ✓Improved sensitivity ✓Reduced sample size required	×Limited availability of stationary phases ×Complexity of synthesis ×Potential degradation of stationary phase
04	Trace Constituents [25]	✓High separation efficiency ✓High resolution ✓Improved sensitivity ✓Reduced sample size required	×Limited availability of stationary phases ×Complexity of synthesis ×Potential degradation of stationary phase

Nanostructured stationary phases have revolutionalized biomedical analysis, biodetection, and origin traceability testing through applications like proteomics, food testing, extracellular vesicle isolation, and virus purification. Continued progress in nanomaterial design, phase engineering and integrated techniques will lead to more sophisticated nano-LC based approaches and widespread use of these methodologies in healthcare, diagnostics, and monitoring of health, food and environment quality [28, 32]. Nanostructured stationary phases thus represent a pivotal enabling technology for analytical sciences with tremendous potential impact. The various workflows involved in using nanostructured stationary phases in liquid chromatography are shown in Figure 3.

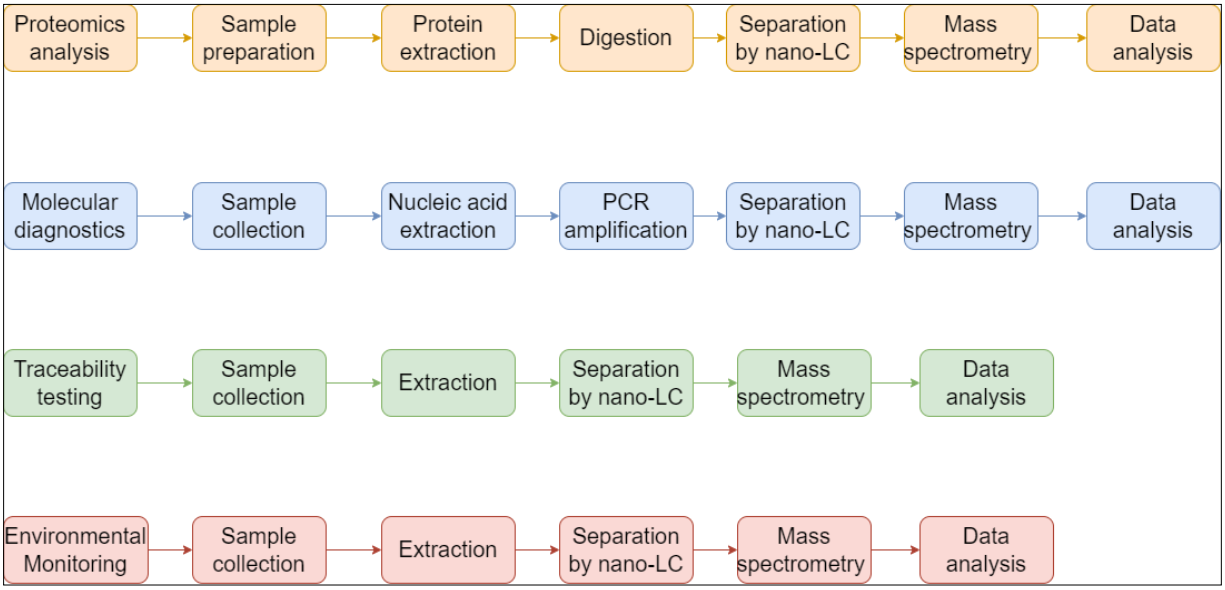

Figure 3 Workflow of a typical experiment using nano-LC approaches for the analysis of proteomics, molecular diagnostics, traceability testing, and environmental monitoring

4. Current Trends and Future Perspectives on Nano-LC Phases

Nanostructured stationary phases have changed liquid chromatography, creating new levels of sensitivity, resolution, applicability and integration with other techniques. Nanoporous silica, graphenic, monolithic and nanoparticle-based phases continue to push the boundaries of biomolecular analysis, molecular diagnostics, food/environment testing and traceability. Some key current and emerging trends include:

4.1. Ultrahigh surface area nanoporous phases

Phases with 3000 m2/g surface area and advanced nanopore architectures for ultrasensitive detection of macromolecules, biomacromolecular complexes and molecular assemblies [2, 3].

4.2. Nanoparticle templating

Layer-by-layer assembly of nanoparticles on phases to create hybrid responsive microdomains and enable sensing, separation, purification and catalysis of samples. Integration of plasmonic, magnetic, quantum dot and other nanoparticles [33] for qualitative and quantitative analysis.

4.3. Nanocage and nanocrystal phases

Metal-organic frameworks, porous carbon nanocages, metal/metal oxide nanocrystals and other engineered nanomaterials as stationary phases with optimized pore size/shape, surface functionality and host-guest interactions [34].

4.4. Monoliths

New monolithic stationary phases including organic, hybrid and biomimetic materials for sample preconcentration, high-throughput separation and integrated reaction-separation. Superior permeability, efficiency and ease of column preparation [35].

4.5. Functionalized 2D materials

Advanced functionalization of graphene, MoS2, WS2 and other 2D nanomaterials to develop highly tailorable stationary phases for bioanalysis, molecular recognition, sensing and separation of small molecules to large biomolecules [36].

4.6. Hyphenated techniques

Tighter integration of nano-LC with MS, NMR, ATR-FTIR and other techniques to gain enhanced molecular-level insights, characterization of unknowns, separate isomers, detect trace components and study complex mixtures in a comprehensive manner [37].

4.7. Microfluidic applications

Use of nanostructured stationary phases in microchips, capillaries and other microfluidic systems for high sensitivity and high-throughput analysis, integration of separation with sample preparation/detection, and development of miniaturized analytical devices [28].

Nanostructured stationary phases will continue to facilitate more sensitive, rapid, highly resolving and multifaceted analysis of biomolecules, contaminants, food/origin constituents and clinical samples. Advanced nanomaterials, nanoparticle engineering, monolith design, surface tailoring and integrated micro-nanofabrication techniques will enable progressively more sophisticated nano-LC based approaches with widespread impact. Nanostructured stationary phases thus represent one of the most exciting and impactful frontiers of chromatography and separation science today with tremendous potential for progress in molecular analysis, healthcare, food safety and environmental monitoring.

5. Conclusion

Nanostructured stationary phases have transformed liquid chromatography, enabling high sensitivity, resolution, and applicability. They have facilitated early disease detection, proteome profiling, food traceability, and environmental monitoring. These materials enable the isolation and analysis of biomolecules, viruses, and trace constituents with high specificity and sensitivity. Nano-LC approaches offer advanced detection, purification, and separation of analytes, with potential for healthcare, food safety, materials analysis, and sustainability. Nanostructured stationary phases are a pivotal frontier in analytical sciences, with immense possibilities for precise, preventive, and personalized healthcare.

Compliance with ethical standards

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Disclosure of Conflict of interest

Authors declare no conflict of interest.

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A study of defaulter and non-defaulter tribal households in Andhra Pradesh

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Abstract
The problem of indebtedness amongst tribals was not only an indication of their poverty but also reflects the wider economic malaise, i.e., lack of education, low purchasing/bargaining power and lack of resources for engaging in gainful activity and meeting emergent expenditure. The objective of the paper is to identify the factors responsible for defaulter and non- defaulter tribal households. Majority of the respondents were in the age group of 31-50 in both the regions. The literacy rate is marginally higher among non-defaulters (56.3) compared to defaulters (52.5) in Seethampeta opposite is true in case of Rampachodavaram such proportions are 51.3 and 60. A major proportion of them belong to cultivators People with more than 10 years of membership is marginally higher in both the defaulters and non-defaulters categories in Seethampeta compared to Rampachodavaram. The average landholding size of defaulters in Seethampeta is 2.9 acres to that of 3.2 acres in Rampachodavaram. More than 41 per cent of the borrowers in Seethampeta come under wilful defaulters category and none expressed such reason in Rampachodavaram. Of the seven reasons for defaulting, five reasons had a lions' share among the defaulters in Seethampeta compared with Rampachodavaram.

Keywords: Age, education, ST loans, borrowings, defaulter, non- defaulter, cropping, GPCMS

Introduction
One of the major objectives of Indian planning is to achieve balanced development not only among different regions, but also among different sections of the society. It is a well-known fact that the tribal population in the country lies at the lowest rung of the ladder of socio-economic development, In spite of the emphasis given to tribal development in the successive plans, the results have not fully percolated into the tribal areas, and the tribal people remained backward both socially and economically.

The problem of indebtedness amongst tribals was not only an indication of their poverty but also reflects the wider economic malaise, i.e., lack of education, low purchasing/bargaining power and lack of resources for engaging in gainful activity and meeting emergent expenditure. As this problem continues, the menace of indebtedness pushes the tribals further into extreme conditions of poverty and forces them to dispense with their meager resources to pay off the loans at exorbitant rates of interest. The problem of tribal indebtedness often got aggravated and compounded with the Government subsidy-cum- loan schemes.

The incidence of indebtedness among agricultural households is observed that households having bigger land size carry a higher debt burden as compared to the ones with lower land size classes. Incidence of indebtedness is higher in agriculturally advanced states such as Andhra Pradesh, Punjab and Karnataka than in the less advanced states such as Bihar, Uttar Pradesh and Odisha. This is mainly because in these states Bihar, Uttar Pradesh and Odisha availability of agricultural credit per hectare of net sown area is very low compared to the national average in terms of incidence of indebtedness. Agricultural households of Punjab, Uttar Pradesh, Andhra Pradesh, West Bengal, Karnataka, Odisha and Rajasthan have greater indebtedness than other selected states of India.(Maurya, SK and Vishwakarma, N, 2021) [2]. All India Debt Investment Survey (AIDIS, 70th round National Sample Survey Office (NSSO) survey) in 2013 (GOI 2013) found that incidence of indebtedness among the rural cultivators had almost reached the level of pre-bank nationalization period of 1960.

At the national level, 46 per cent of the cultivators and 29 per cent of non-cultivator households were indebted. Share of credit to farmers from money lenders has actually increased to 29.6 per cent in 2013. The money lenders' hand has been strengthened in the rural areas mainly due to the apathy of the public sector banks to disburse the small ticket credit to small and marginal peasants (Pathak A 2020) [1]. The main reason for the tribal household's indebtedness is their budget deficit which prompts them to go for loans to fill up this deficit to meet their needs. About 94 per cent of the tribal in Keonjhar are dependent on farming, 46 per cent of them get their income from wages which implies their dependence on others' land for earning their income. Study found that the Dombs paid them only a single bottle of wine for a lease of fruit bearing orange trees worth ₹1500 or 6 jack fruit trees yielding fruits of the same value for years. The tribal are forced to approach the private lenders to meet their consumption expenditures and lavish spending on social customs and rituals, addiction of intoxicants, health care needs etc being the major ones besides others. Many of them were found to be engaged as bonded labour on their own land which is now in the possession of the money lenders Sanjeeta K. Devi and Swapnamoyee P Palit (2019) [3]. The awareness levels of tribal people with respect to various financial products and services" and their ability to select the appropriate one in the Wayanad district among the tribal people. It was significantly different (at 5 per cent level) in all the fifteen variables of IFI between rural and urban tribes Ramanujam,V and V.R. Dhanyamol (2019) [4]. Chi-square test reveals that there is no significant difference among tribe communities in respect of having bank accounts. Literature on financial exclusion/banking exclusion suggests five factors *viz.* Price exclusion, marketing exclusion, condition exclusion, access exclusion, self-exclusion and Geographical exclusion that could lead to financial/banking exclusion. Only 10.5 per cent of tribes have reported that they opened accounts following pressure from banks. The study concludes that there is significant difference among tribal communities as far as the factors that influence them to open accounts are concerned Pradeep Kumar, B (2015) [5].

Andhra Pradesh is one of the major states with predominant tribal population accounting for 5.33 per cent of the total population, as per the 2011 Census. The tribal unrest in Andhra Pradesh attracted the attention of academics to reflect on tribal indebtedness. The main objective of the paper is to compare the defaulter and non- defaulter tribal households in Rampachodavaram and Seethampeta mandals. The study has been chosen two mandals *viz*., Rampachodavaram in East Godavari district and Seethampeta in Srikakulam district of Andhra Pradesh. A total of 160 samples were collected each from Seethampeta and Rampachodavaram mandals to conduct the study on financing of tribal agriculture through Girijan Primary Co-operative Marketing Societies (GPCMS) in Andhra Pradesh. Of the total samples, 80 samples each were defaulters and non-defaulters in both mandals. The reference period of the study was August-November, 2020.

Age Group

In Seethampeta mandal, the highest defaulting age group is 41-50 years with a weightage of 37.5 per cent, the second most defaulting age group is 31-40 years with 33.8 per cent. The lowest defaulting age group is 60 plus years where the weightage is 2.5 per cent. The weightage among other age groups was 15.0 per cent for below 30 years, 11.3 per cent for 51-60 years. Such share for non-defaulters stood at 40.0 per cent for 41-50 years, 23.7 per cent for 31-40 years, 18.7 per cent for below 30 years, 13.8 per cent for 51-60 years and 3.8 per cent for above 60 years. Of the total samples collected amongst defaulters in Rampachodavaram, 46.2 per cent were from 31-40 years, 26.3 per cent from 41-50 years, 16.3 per cent from 51-60 years, 10.0 per cent from below 30 years and 1.2 per cent above 60 years. Among the non-defaulters, such share remained at 42.5 per cent for 31-40 years age group, 32.5 per cent for 41-50 years, 12.5 per cent for below 30 years, 11.2 per cent for 51-60 years and 1.2 per cent for above 60 years. The details of age wise distribution in both the regions are presented in Table 1. It is observed that age group 41-50 has the highest concentration of both defaulters (37.5%) and non-defaulters (40%) in Seethampeta while in Rampachodavaram such proportions are 46.2 and 42.5 per cent in age group of 31-40 respectively among defaulters and non-defaulters

Table 1: Age group of the defaulter and non-defaulter households in the two regions

Si. No.	Age Group	Seethampeta				Rampachodavaram			
		Defaulters		Non-Defaulters		Defaulters		Non-Defaulters	
		No.	%	No.	%	No.	%	No.	%
1	Below 30	12	15.0	15	18.7	8	10.0	10	12.5
2	31-40	27	33.8	19	23.7	37	46.2	34	42.5
3	41-50	30	37.5	32	40.0	21	26.3	26	32.5
4	51-60	9	11.2	11	13.8	13	16.3	9	11.3
5	Above 60	2	2.5	3	3.8	1	1.2	1	1.2
	Total	80	100.0	80	100.0	80	100.0	80	100.0

Source: Field Survey

Caste Category

Table 2 presents the data of defaulters and non-defaulters by caste category in study area. In Seethampeta, the share of Jatapu and Savara castes among both defaulter and non-defaulters stood at 62.5 per cent and 37.5 per cent respectively. In Rampachodavaram, Konda Dora has the highest defaulter and non-defaulter ratio of 35 per cent each. The ratio of defaulters and non-defaulters stood equal for all other castes with 27.5 per cent for Konda Reddy, 15 per cent for KondaKapu, 12.5 per cent for Konda Kammari and Valmiki (10%) in Rampachodavaram. There are different castes across the two sample areas. More than 62 per cent of defaulters and non-defaulters belongs to Jatapu in Seethampeta. Konda Dora and konda Reddy are the major castes in Rampachodavaram.

Table 2: Caste category of the defaulter and non-defaulter households in the two regions

S. No.	Caste	Seethampeta				Rampachodavaram			
		Defaulters		Non-Defaulters		Defaulters		Non-Defaulters	
		No.	%	No.	%	No.	%	No.	%
1	Jatapu	50	62.5	50	62.5	-	-	-	-
2	Savara	30	37.5	30	37.5	-	-	-	-
3	Konda Dora	-	-	-	-	28	35.0	28	35.0
4	Konda Reddy	-	-	-	-	22	27.5	22	27.5
5	KondaKapu	-	-	-	-	12	15.0	12	15.0
6	Valmaki	-	-	-	-	8	10.0	8	10.0
7	KondaKammari	-	-	-	-	10	12.5	10	12.5
	Total	80	100.0	80	100.0	80	100.0	80	100.0

Source: As ex ante

Educational Status

The sample characteristics for defaulters and non-defaulters by education category is presented in Table 3. Most of the defaulters and non-defaulters belong to the literate group in both the regions. According to the data, 52.5 per cent of the defaulters in Seethampeta were literate, followed by 40.0 per cent illiterate and 7.5 per cent with primary education. In Rampachodavaram, 60.0 per cent of the defaulters were literate followed by 38.8 per cent Illiterate and 1.2 per cent with primary education. Amongst non-defaulters too, the share remains almost similar. In Seethampeta, a total of 56.3 per cent non-defaulters were literate followed by 33.7 per cent illiterate and 10.0 per cent with primary education. Such share for non-defaulters in Rampachodavaram remained at 51.3 per cent for literate, 36.3 per cent for illiterate and 12.4 per cent with primary education. Across the two regions, the literacy rate is marginally higher among non-defaulters (56.3) compared to defaulters (52.5) in Seethampeta opposite is true in case of Rampachodavaram such proportions are 51.3 and 60.

Table 3: Educational status of the defaulter and non-defaulter households in the two regions

Si. No.	Educational Status	Seethampeta				Rampachodavaram			
		Defaulters		Non-Defaulters		Defaulters		Non-Defaulters	
		No.	%	No.	%	No.	%	No.	%
1	Illiterate	32	40.0	27	33.7	31	38.8	29	36.3
2	Literate	42	52.5	45	56.3	48	60.0	41	51.3
3	Primary	6	7.5	8	10.0	1	1.2	10	12.4
	Total	80	100.0	80	100.0	80	100.0	80	100.0

Source: As ex ante

Occupation

An analysis of occupation of the respondents show that most are cultivators and agricultural labour. Table 4 shows that among the defaulters in Seethampeta 56.3 per cent were cultivators, 41.3 per cent were agricultural labour and 2.4 per cent were in non-agriculture labour. Among the non-defaulters in Seethampeta 52.4 per cent were cultivators, 46.3 per cent were agricultural labor and 1.3 per cent are non-agricultural labour. Among defaulters in Rampachodavaram, 61.2 per cent were from cultivators and 38.8 per cent from agricultural labour. Such share for non-defaulters in Rampachodavaram stood at 57.4 per cent for cultivators, 41.3 per cent for agricultural labour and 1.3 per cent for non-agriculture. This clearly shows that a major proportion of the defaulters are the cultivators in both the sample mandals while Rampachodavaram has slightly higher proportion compared to Seethampeta (61.2 to 56.3). Exactly the same kind of trend is found among the non-defaulters. In the agricultural labour households, both defaulters and non-defaulters are more in Seethampeta compared to Rampachodavaram.

Table 4: Occupation of the defaulter and non-defaulter households in the two regions

Occupation	Seethampeta				Rampachodavaram			
	Defaulters		Non-Defaulters		Defaulters		Non-Defaulters	
	No.	%	No.	%	No.	%	No.	%
Cultivators	45	56.3	42	52.4	49	61.2	46	57.4
Agricultural Labour	33	41.3	37	46.3	31	38.8	33	41.3
Non-Agrl. Labour	2	2.4	1	1.3	0	0.0	1	1.3
Total	80	100.0	80	100.0	80	100.0	80	100.0

Source: As ex ante

Type of House

Table 5 gives the data on the types of houses of the sample respondents in the study area. The data reveals that more number of people live in semi-pucca houses in both the mandals, followed by those living in pucca houses and kutcha houses. Another interesting observation is that highest number of non-defaulters in both the mandals live in semi-pucca houses (Seethampeta: 50 and Rampachodavaram: 45 per cent). At the same time highest number of defaulters also live in the semi-pucca houses in both the sample mandals (Seethampeta: 45 and Rampachodavaram: 43.2 per cent). The share of those staying in kutcha house is 25.0 per cent for defaulters and 22.5 per cent for non-defaulters in Seethampeta. The composition of defaulters in Rampachodavaram remained at 19.8 per cent for kutcha, 43.2 per cent for semi- pucca and

37 per cent for pucca house. Such share for non-defaulters in Rampachodavaram stood at 18.8 for kutcha, 45 for semi pucca and 36.2 for pucca houses. The analysis clearly shows that more than two thirds of the households in both the mandals live in kutcha or semi-pucca houses which reflects on their economic status. This shows that there is a need to construct pucca houses through housing schemes implemented by the Government.

Table 5: Type of House of the defaulter and non-defaulter households in the two regions

S. No.	Type of House	Seethampeta				Rampachodavaram			
		Defaulters		Non-Defaulters		Defaulters		Non-Defaulters	
		No.	%	No.	%	No.	%	No.	%
1	Kutcha	20	25.0	18	22.5	16	19.8	15	18.8
2	Semi Pucca	36	45.0	40	50.0	35	43.2	36	45.0
3	Pucca	24	30.0	22	27.5	30	37.0	29	36.2
	Total	80	100.0	80	100.0	80	100.0	80	100.0

Source: As ex ante

Number of Workers

The number of workers in defaulter and non-defaulter households in the two regions is presented in Table 6. According to the data, majority of the households in both the regions (Seethampeta and Rampachodavaram) for both defaulters and non-defaulters have two to three workers in their household. The field data shows that 42.5 per cent and 47.5 per cent of the defaulters have two and three workers each respectively in their family. For non-defaulters the corresponding percentages were 43.7 (two workers) and 38.8 (three workers). There is a similar trend for both defaulters and non-defaulters in Rampachodavaram mandal. The average number of workers slightly higher for defaulters at 2.5, and 2.4 for non-defaulters in Seethampeta and such figures were 2.4 and 2.2 respectively in Rampachodavaram.

Table 6: Number of workers in defaulter and non-defaulter households in the two regions

S. No.	Number of Workers	Seethampeta				Rampachodavaram			
		Defaulters		Non-Defaulters		Defaulters		Non-Defaulters	
		No.	%	No.	%	No.	%	No.	%
1	One	4	5.0	9	11.2	7	8.8	17	21.3
2	Two	34	42.5	35	43.7	37	46.3	34	42.5
3	Three	38	47.5	31	38.8	35	43.7	27	33.8
4	Four & Above	4	5.0	5	6.3	1	1.2	2	2.4
	Total	80	100.0	80	100.0	80	100.0	80	100.0
Average No. of Workers		2.5		2.4		2.4		2.2	

Source: As ex ante

Membership in GPCMS

Table 7 gives the data on the membership in GPCMS of defaulters and non-defaulters in the two regions. About 52.5 per cent of defaulters have membership of GPCMS for more than seven years while 47.5 per cent of the non-defaulters have similar standing in Seethampeta. In Rampachodavaram the corresponding figures for defaulters and non-defaulters were 42.5 and 38.8 per cent respectively. People with more than 10 years of membership is marginally higher in both the defaulters and non-defaulters categories in Seethampeta compared to Rampachodavaram and less than four years of membership experience with GPCMS is lower among two categories in Seethampeta than that of Rampachodavaram.

Table 7: Membership in GPCMS of the defaulter and non-defaulter households in the two regions

Membership in Years	Seethampeta				Rampachodavaram			
	Defaulters		Non-Defaulters		Defaulters		Non-Defaulters	
	No.	%	No.	%	No.	%	No.	%
≤ 4	13	16.2	10	12.5	14	17.5	23	28.7
5	10	12.5	16	20.0	18	22.5	13	16.2
6	9	11.3	11	13.8	12	15.0	10	12.5
7	12	15.0	13	16.2	10	12.5	9	11.3
8	16	20.0	15	18.8	13	16.2	15	18.8
9	14	17.5	10	12.5	11	13.8	7	8.7
10 & Above	6	7.5	5	6.2	2	2.5	3	3.8
Total	80	100.0	80	100.0	80	100.0	80	100.0

Source: As ex ante

Landholding Particulars

Table 8 shows the landholding particulars of the defaulters and non-defaulters in the selected sample region. The data on landholdings reveal that 35 per cent (largest group) in Seethampeta and 48.8 per cent (largest group) in Rampachodavaram of the defaulters were having a landholding of the size of 3 acres. This is closely followed by 32.5 and 27.5 per cent of the defaulters having 2 acres of landholding in Seethampeta and Rampachodavaram respectively. Among non-defaulters, 43.8 per cent in Rampachodavaram has 3 acres while in Seethampeta 38.8 per cent of the non-defaulters are having a landholding of only 2 acres. In both the sample mandals, the highest concentration of defaulters is found in the 3 acre landholdings. The average landholding size of defaulters in Seethampeta is 2.9 acres to that of 3.2 acres in

Rampachodavaram. Similarly among the non-defaulters also the Rampachodavaram tribal households has slightly larger average landholding (2.8 acres) to those in Seethampeta (2.5 acres). In the whole of the sample regions, there is no wet land, as expected because of the hilly terrain where the tribe people live.

Table 8: Landholding particulars of the defaulter and non-defaulter households in the two regions

Size of Landholding (in Acre)	Seethampeta				Rampachodavaram			
	Defaulters		Non-Defaulters		Defaulters		Non-Defaulters	
	No.	%	No.	%	No.	%	No.	%
< 1	10	12.5	13	16.2	5	6.2	9	11.2
2	26	32.5	31	38.8	22	27.5	27	33.8
3	28	35.0	25	31.2	39	48.8	35	43.8
4 & above	16	20.0	11	13.8	14	17.5	9	11.2
Total	80	100.0	80	100.0	80	100.0	80	100.0
Type of Land (in Acre)								
Dry Land	232	100.0	200	100.0	256	100.0	224	100.0
Wet Land	0	0.0	0	0.0	0	0.0	0	0.0
Total	232	100.0	200	100.0	256	100.0	224	100.0
Average Land	2.9		2.5		3.2		2.8	

Source: As ex ante

Cropping Pattern

Table 9 provides an explanation of the cropping patters of defaulters and non-defaulters in the sample areas. Paddy, cashew and red gram are the three top crops cultivated by defaulters in Seethampeta. The share of these three crops is 24.1 per cent, 20.7 per cent and 10.3 per cent respectively. The non-defaulters in Seethampeta follow a different pattern as paddy; red gram and ragi are the three prioritized crops with a share of 31.2, 12.4 and 10.0 per cent respectively. The top choice for corps for both defaulters and non-defaulters is paddy for Rampachodavaram. There share is 32.8 and 31.4 per cent respectively. The other preferred crops are cashew and ragi in the region. The average cropped areas for defaulters and non-defaulters are 2.90 acres and 2.50 acres in Seethampeta and 3.2 acres and 2.8 acres in Rampachodavaram. Paddy is the major crop in both areas, about 33 and 31 per cent of the total cropped area come under this crop in defaulters and non-defaulters in Rampachodavaram and these figures are 24 and 31 per cent respectively in Seethampeta. Cashew had a lions' share (20.7%) and grains like samalu, korralu and ganti are also grown in these areas.

Table 9: Cropping pattern of defaulter and non-defaulter households in the two regions (Average Area in Acres)

Crop	Seethampeta				Rampachodavaram			
	Defaulters		Non-Defaulters		Defaulters		Non-Defaulters	
	Area	%	Area	%	Area	%	Area	%
Paddy	0.70	24.1	0.78	31.2	1.05	32.8	0.88	31.4
Ragi	0.13	4.5	0.25	10.0	0.25	7.8	0.15	5.4
Maize	0.18	6.2	0.14	5.6	0.00	0.0	0.00	0.0
Pineapple	0.09	3.1	0.08	3.2	0.00	0.0	0.00	0.0
Sesamum	0.20	6.9	0.13	5.2	0.22	6.9	0.08	2.9
Cashew	0.60	20.7	0.22	8.8	0.32	10.0	0.25	8.9
Redgram	0.30	10.3	0.31	12.4	0.16	5.0	0.16	5.7
Greengram	0.00	0.0	0.00	0.0	0.14	4.4	0.20	7.1
Blackgram	0.00	0.0	0.00	0.0	0.18	5.6	0.15	5.4
Horsegram	0.00	0.0	0.00	0.0	0.20	6.3	0.06	2.1
Samalu	0.15	5.2	0.20	8.0	0.14	4.4	0.16	5.7
Korralu	0.13	4.5	0.10	4.0	0.06	1.9	0.17	6.1
Topoica	0.00	0.0	0.00	0.0	0.14	4.4	0.10	3.6
Cotton	0.00	0.0	0.00	0.0	0.05	1.6	0.12	4.3
Ganti	0.13	4.5	0.08	3.2	0.13	4.1	0.13	4.6
Turmeric	0.12	4.1	0.15	6.0	0.00	0.0	0.00	0.0
Jowar	0.00	0.0	0.00	0.0	0.16	5.0	0.19	6.8
Groundnut	0.17	5.9	0.06	2.4	0.00	0.0	0.00	0.0
Total	2.90	100.0	2.50	100.0	3.20	100.0	2.80	100.0

Source: As ex ante

Source-wise Borrowings

Table 10 revealed the data on the source-wise borrowings of defaulters and non-defaulters the study regions. The sources of borrowing were classified into four groups, namely friends & relatives, money lenders, traders and GPCMS. The highest loan amount was provided by GPCMS to the non-defaulters Rs. 32400 (82.5%) and defaulters Rs.30800 (74.6%) in Seethampeta region. In case of Rampachodavaram, the highest amount received by defaulters Rs. 31600 (79%) and non-defaulters Rs. 30350 (81%). Next to GPCMS, traders and money lenders provided loans to the tribal households in the two regions and friends & relatives provided a meager amount of loan in both the regions. The average amount of loan borrowed by defaulters (Rs. 41300) and non-defaulters (Rs. 39250) were marginally more in Seethampeta compared with Rampachodavaram which was reported at Rs. 40000 and Rs. 37500 respectively in Seethampeta and Rampachodavaram.

On the whole, the highest proportion of loan amount was provided by GPCMS to the non-defaulters in both the regions which accounted for 82.5 and 80.9 respectively in Seethampeta and Rampachodavaram. While those defaulters in Rampachodavaram and Seethampeta reported that 79 and 74.6 per cent loans were provided by the GPCMS. Traders provided 13.3 and 8.2 per cent of the loan amount to the defaulters and non-defaulters in Seethampeta, while it was8.9 and 7.7 per cent in Rampachodavaram. This shows that both the defaulters and non-defaulters have received more than 3/4th of the loans from the GPCMS. However, both traders and money lenders are still having influence by providing considerable amounts of loans to the tribals in the agency areas.

Table 10: Source- wise Borrowings (Average) of the Defaulter and Non-Defaulter Households in the Two Regions:2019-2020

Source	Seethampeta				Rampachodavaram			
	Defaulters (80)		Non-Defaulters (80)		Defaulters (80)		Non-Defaulters(80)	
	Amount	%	Amount	%	Amount	%	Amount	%
Friends & Relatives	1500	3.6	1050	2.7	1950	4.9	2200	5.9
Money Lenders	3500	8.5	2600	6.6	2900	7.3	2050	5.5
Traders	5500	13.3	3200	8.2	3550	8.9	2900	7.7
GPCMS	30800	74.6	32400	82.5	31600	79.0	30350	80.9
Total	41300	100.0	39250	100.0	40000	100.0	37500	100.0

Source: As ex ante

Reasons for Default of ST Loans

Defaulters in both the regions were asked to indicate the important reasons for loan default to the GPCMS. Among the reasons stated for default consists of having no knowledge/awareness of due dates, society officials not approaching the borrowers for repayment (not following up with the borrowers), inadequate income generation from agriculture, crop failure, unforeseen family expenditures, debts with high rate of interest from non-institutional lenders were to be repaid first and willful defaulting. These details presented in Table 11 shows as many as 22(27.5%) and 13(16.3%) of defaulters stated that they had no knowledge of due dates for repayment of their loans in Seethampeta and Rampachodavaram regions respectively, A higher proportion of defaulters (42.5%) indicated that society officials did not approach for repayment of loan in Seethampeta while such proportion was 33.8 percent in Rampachodavaram. The major reasons for defaulting loans to the GPCMS were stated to be inadequate income from agriculture (reported at 82.5 per cent in Seethampeta and 72.2 per cent in Rampachodavaram), crop failure 65 and 47.5 per cent and unforeseen family expenditure 49 and 50 per cent respectively in these two sample mandals. About 19per cent in Seethampeta and 10 per cent of the defaulting borrowers in Rampachodavaram reported that debts with high rate of interest were repaid first to avoid hardships and litigations. The willful defaulters were found only in Seethampeta region (41.3%). The analysis clearly show that there were four main reasons for defaulting in both the regions namely, inadequate income from agriculture (82.5%), crop failure (65%), society officials not approaching for repayment (42.5%), and unforeseen family expenditure (40%) in Seethampeta while the corresponding figures for Rampachodavaram were 72.5, 47.5, 33.8 and 50 per cent respectively. Surprisingly 41.3 per cent of the borrowers in Seethampeta come under willful defaulters category and none expressed such reason in Rampachodavaram of the seven reasons for defaulting, five reasons had a lions' share among the defaulters in Seethampeta compared with Rampachodavaram. The data suggests that there was a need to reschedule the period of repayment of agricultural credit by the GCC whenever crop failure occurred in tribal areas and to have better follow up by the officials of GCC for loan recovery, keeping in mind the illiterate nature of tribe populations and their lack of financial knowledge.

Table 11: Reasons for Default of ST loans by the defaulter households in the two regions

Reasons	Defaulters			
	Seethampeta (80)		Rampachodavaram (80)	
	No.	%	No.	%
No knowledge of due dates	22	27.5	13	16.3
Society officials did not approach me for repayment	34	42.5	27	33.8
Inadequately income from agriculture	66	82.5	58	72.5
Crop failure	52	65.0	38	47.5
Unforeseen family expenditure	32	40.0	40	50.0
Debts with high rate of interest were repaid first	15	18.8	8	10.0
Willful default	33	41.3	0	0.0

Source: As ex ante

Conclusion

To sum up, the highest proportion of defaulters and non-defaulters are in the age group of 41-50 in Seethampeta, whereas in Rampachodavaram such proportion are high in the age group of 31-40. In Seethampeta jatapu caste is predominant and kondadora is more Rampachodavaram. In both the regions illiterate are more among defaulters compared with non-defaulters. Cultivators are significantly more in defaulters as well as non-defaulters in Rampachodavaram region. Majority of the tribal households are living in semi-pucca houses in the study area. Three and two worker families are more among defaulters and non-defaulters respectively in both the regions. About 35 per cent of defaulters having three acres of land and it is 39 per cent of non-defaulters having two acres of land in Seethampeta, whereas 49 per cent and 44 per cent of defaulters and non-defaulters having three acres of land in Rampachodavaram. The proportion of more than three acres

of owned land accounted for higher in defaulters and non-defaulters in Rampachodavaram compared with Seethampeta. The highest proportion of loan amount was provided by GPCMS to the non-defaulters in both the regions which accounted for 82.5 and 80.9 respectively in Seethampeta and Rampachodavaram. Of the seven reasons for defaulting, five reasons had a lions' share among the defaulters in Seethampeta compared with Rampachodavaram. The major reasons for the tribal indebtedness has been influenced by several social, geographical, economic and other cultural factors combining with each other. The data suggests that there was a need to reschedule the period of repayment of agricultural credit by the GCC whenever crop failure occurred in tribal areas and to have better follow up by the officials of GCC for loan recovery, keeping in mind the illiterate nature of tribe populations and their lack of financial knowledge.

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