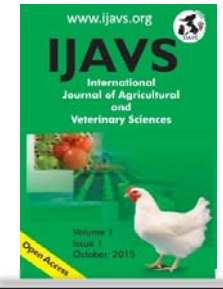

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RESEARCH ARTICLE

Production and Toxicological Evaluation of Foam-Mat Dehydrated Banana Powder for Food Applications

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ABSTRACT:

This study investigated the toxicological effects of foam-mat dried banana powder in order to assess its safety for use as food ingredient. Two banana cultivars, Chinensis (PAR) and giant Cavendish (SNR) at soft ripe stage were obtained and pectinase hydrolysed banana pulp pastes of each cultivar was prepared. A 2.5% suspension of glyceryl-monostearate (GMS) as edible foam agent was incorporated into the pastes at 0.4%, whipped, dried, milled (375 micron powder), and used for toxicological evaluation. Fifty male adult rats were fed extracts of banana samples at levels of 150, 250, 750 and 1000mg/kg rat weight for 21 days. The rats' blood serum were used for the biochemical/enzyme analyses and complete blood counts. The rats' tissue organs (liver, kidney, brain, heart, intestine) were also used for histopathological examinations. The serum protein ranged from 6.8 – 7.2g/dL in rats administered PAR and SNR extracts. Albumin and globulin contents of serum ranged from 4.1–4.5 and 2.5–3.9g/dL, respectively and the blood glucose levels varied from 120 – 125 and 120 – 127 mg/dL, respectively. The serum *alkaline phosphatase* (ALP), *alanine amino transferase* (ALT) and *aspartate amino transferase* (AST) contents of the rats ranged from 77–92, 26–39, and 38–45µg/L respectively. The average packed cell volume (PCV) ranged from 43.5–47.0% for rats fed PAR and SNR extracts, Haemoglobin (Hb) (14.1–14.6 g/100mL), RBC (7.3–7.8x10^6 µg/L), WBC (6.290–9.612 µg/L) of the rats varied. Rats administered SNR and PAR extracts (150–1000mg/kg body wt) had liver that showed moderately congested hepalocellular sinusoids, no visible lesions; brain with normally congested vessels, no visible lesion, heart with no myocardial degeneration similar to those of the control. The kidney showed moderate tubular epithelium, intestine with normal architecture, villi and no visible lesions. The use of GMS as edible foam agent in banana powder was safe and constituted no health hazard to experimental rats.

Keywords: *Foam-agent, banana powder, toxicological tests, biochemical analysis, tissue organ histopathology.*

INTRODUCTION

Banana powder is obtained from ripe banana fruit pulp. It is a useful ingredient for different food applications such as natural flavourant, sweetener and micro nutrients source for baby foods, yoghurt, cake mixes, bread, biscuit, custard, fruit drinks, nectar, ice-cream, soft food items (Author, 2010, Crowther 1999). In order to improve the quality of banana powder, different dehydration methods have been

investigated. These include drum drying, cabinet drying, osmotic drying, hypobaric dehydration, spray drying and foam-mat dehydration (Alakali and Ariahu 2007; Jackson and Mohammed 2001).

Foam-mat drying was preferred to other methods for producing high quality banana powder (Orishagbemi *et al.* 2010, Kudra and Ratti 2008). Foam-mat drying is a food dehydration technique for semi-solid and liquid materials containing not more than 35% solid contents (Rajkumar *et al.,* 2007). It involves incorporation of edible foaming agents, and or stabilizer which make product retain original flavour, colour, nutrients and reconstitution property (Rajkumar *et al.* 2007; Falade, *et al.*, 2003).

Foaming-agents that have been used for various food products included glycerylmonostearate (GMS) for soymilk, fluid animal milk, tomato juice, mango puree, hydrolyzed banana pulp, GMS and egg albumin for cowpea, monoglycerylpalmitate (MGP) and methocel for citrus, apple, star fruit juices, soy protein and gelatine hydrolysate for mango, banana (Kudra and Ratti 2008; Raharitsifa *et al*., 2006; Doymez 2005, Sinkat and Castaigne, 2004). However, reports on the toxicological effects of the edible foam agents and stabilizers in foam-mat dried products as human foods are scarce in the literature. The safety of the chemical foaming substances needs to be evaluated by appropriate toxicological tests.

Thus, the objective of this study was to produce and assess the toxicological effects of foam–mat dried banana powder intended for different food applications.

MATERIALS AND METHODS

Raw Materials and Sources

Two cultivars of banana fruits, *Chinensis* coded PAR and *giant Cavendish* SNR found suitable for processing into banana powder were obtained as fresh soft ripe fruits (23 – 25^{o} Brix) from Ojeh market at Ibadan township. They were identified by experts at National Institute of Horticultural Research (NIHORT), Ibadan. Glycerylmonostearate (GMS) edible foaming agent was obtained from reputable store in Ojota–Lagos. This chemical was produced by Marietta GA and Edlen International, USA. Fresh stock of pectinase enzyme (1.5mL.Sec^{-1} activity, 40°C optimum temperature, 3.5-4.2 pH range) was obtained from Biotechnology Laboratory, Federal Institute of Industrial Research, Oshodi (FIIRO), Lagos.

Preparation of enzyme hydrolyzed banana paste, foaming agent and dehydration procedures

The method described by Orishagbemi *et al.* (2010) was used. Ripe banana pulp of PAR and SNR respectively were converted into smooth colloidal paste by pulping using Akira Kitchen blender. The fresh paste was pasteurized at 60°C for 15 min, cooled to 40°C and then mixed with the prepared pectinase enzyme diluent (paste: enzyme ratio of 10:1). Then incubated at 40^{o}C for 6 h (Akinola, *et al.* 2001) to obtain pulpy juice of 20–22% solid contents (preserved with 0.15g sodium metabisulphite (SMS) per kg pulpy juice), cooled and kept under refrigeration prior to use. The foaming agent (GMS) was applied as 0.4% of pulpy juice (based on the result of the preliminary study that involved 0.3, 0.4, 0.5 and 0.6% concentration of GMS in which 0.4%

concentration produced maximum foam volume increase). Four gramme GMS was prepared in a 2.5% suspension by dissolving it in 156mL distilled water (98^{o}C) with stirring.

The suspension was mixed with 1kg pulpy banana juice, whipped using Kenwood mixer (model BL 330) at 600 rpm, 6 min (earlier work which involved 4, 6, 8 and 10 min showed that whipping for 6 min produced maximum foam volume). Then, 500g whipped sample per batch was spread on thin layer (2–3mm thickness) stainless steel trays, dried in a laboratory tray dryer (model TD 252 by Armsfield Limited, England) at 60^{o}C, 1.8m/s air speed to constant weight. This was then dried at 70^{o}C to further reduce moisture to about 5.40%.

Dried banana flake was scrapped, milled into 375 micron particle size powder using Apex 2145 hammer mill. Each sample was packaged in HDPE film (0.22mm gauge) and then heat sealed. Larger quantity of each was produced following similar procedures. They were packaged in 200g per bag and 10 bags of each sample were obtained). These placed inside black poly bag, tied and stored at ambient temperature (28 $\pm$ 2 ^{o}C) for animal feeding experiments.

Toxicological Tests

Toxicological evaluation involved rat feeding experiments by administration of sample extracts and feeding with grower's mash for 21 days. Five percent (5%) extracts (50g/L distilled water) of both PAR and SNR banana powder were prepared and the extracts in hermetically sealed bottles were kept under refrigeration and used for not more than three days. Thereafter, fresh extract was prepared until the end of the experiment.

Rat feeding and extract administration

Fifty male adult albino rats weighing 150 – 200g were obtained and randomly distributed into 5 groups of ten rats. Then rats were tagged using picric acid and kept in cages at the animal house, Department of Veterinary physiology and pharmacology, University of Ibadan, Ibadan. One group was tagged as the control. The rats were fed with grower's mash and de-ionized water ad-libitum for 10 days before the commencement of oral administration of sample extracts simultaneously with feeding. Extracts were administered to rats based on body weight at 4 different concentrations (150, 250, 750 and 1000 mg extract solid/kg weight of rat) and distilled water was used as control (3 mL/rat daily) instead of extract, in order to test for the toxicity of foaming agent used. At the end of test period, experimental rats were re-weighed, then individually placed inside desiccator filled with diethyl ether to anaesthetize them and removed after 2 min. Then blood was collected through ocular method and preserved for analysis.

Then cervical dislocation was performed on the rat and this was followed by opening – up and quick harvesting of tissue organs (liver, kidney, brain, heart and intestine). They organs were preserved in 10% formalin solution for histopathological examination which were carried out in the Department of Veterinary Pathology, University of Ibadan, Ibadan, Nigeria. Frozen serum was used for complete blood count (PCV, Hb, Rbc, Wbc, Platelet, lymphocyte, erythrocyte, neutrophils, monocyte and eosinophiles) according to methods described by Davies

et al., (1984). Enzyme and biochemical parameter analyses of serum including albumin, protein, glucose, creatinine, alanine aminotransferase (ALT), aspartate aminotransferase (AST) and alkaline phosphatase (ALP) were determined according to methods described by Randox (2008), Oshundahunsi and Aworh (2003) and Davies *et al.,* 1984).

RESULTS AND DISCUSSION

Biochemical effects of foam-mat dried banana powder on experimental rats.

Table 1 shows the biochemical parameters of the experimental rat blood serum. The serum protein concentrations ranged from 6.9 to 7.2 g/dL in rats fed PAR extract (Groups 1- 4) which increased with increased concentration of banana extract. However, they were slightly lower than serum proteins (7.3±0.04 g/dL) of the control rats in group 5. The serum protein ranged from 6.8-7.4 g/dL in rats fed SNR extract and decreased with increased concentration (150-1000 mg extract/kg body weight of rat). Apparently, there was no significant difference ($p>0.05$) between serum proteins in experimental rats and those of the control. This showed that the extract did not contribute to the increased serum protein because banana powder contained mainly carbohydrates in form of soluble solids as sugars (Table 1). Similar report was reported by Onigbinde (2005) in a monograph on biochemical studies of various processed and unprocessed foods.

Both albumin (4.1-4.5 g/dL) and globulin (2.5-3.9 g/dL) contents of the serum followed the same pattern as protein in rats fed both PAR and SNR extracts. The albumin contents fell within the normal values (3.8-4.8 g/dL) in adult rats as reported by Grant (1987). Therefore, the water balance in serum and plasma of experimental rats would be maintained and the transport and storage of hormones and fatty acids would be enhanced since albumin responsible for these functions is at normal level. The rats fed SNR and PAR extracts gained more weight (24.4-29.5%) and (15.1-25.7%) respectively than control rats (8.7-10.1%). The conversion of serum proteins to make cells grow rapidly in experimental rats than the control rats might be responsible for increased rat weight at the end of test period.

The creatinine contents of serum obtained from rats fed PAR and SNR extracts at the various levels (150-1000 mg/kg body weight) increased with the concentration but did not exceed 0.60±0.001 mg/dL which was within the limits of 0.3-0.9 mg/dL for experimental animals (Randox, 2008). Creatinine is used in the assessment of kidney functioning.

The values obtained for this study were within the recommended values, suggesting that no kidney impairment occurred to the experimental rats as shown by the histopathology report (Table 3). Table 3 showed no significant lesion in the kidneys of the rats in Groups 1-4, results which were similar to the control (Group 5). This is an indication that glycerylmonostearate (GMS), foaming agent used at 0.4% level in banana powder had no toxic effect on the kidney of experimental rats.

Blood glucose levels of rats fed with PAR extract ranged from 120-126 mg/dL while those of the rats fed SNR extract were 120-127 mg/dL. These values increased with increased concentration of banana extract (150 - 1000mg/kg body weight). The

control rats had 120 ± 0.31mg blood glucose/dL which was similar to that of the Group 1 rats (150 mg extract/kg body weight). Greater blood glucose level in experimental rats than the control was attributable to higher amount of metabolizable soluble sugars in banana powder.

The amounts of blood glucose in the serum of the experimental rats were however, not greater than recommended maximum limit of 250mg/dL reported by Davies *et al*. (1984). This indicated that PAR and SNR banana powder could not cause any hyperglycaemia and the associated symptoms when used as food ingredient in the experimental rats.

Serum alkaline phosphatase (ALP), alanine aminotransferase (ALT) and aspartate aminotransferase (AST) contents of the experimental rats (Groups 1-5) ranged from 77 to 92 µ/L, 26-39 µ/L and 38-45 µ/L, respectively. There were no specific trend in the results which were similar to those of the control. These values were within the range of safety for ALP (60-170 WL), ALT (up to 120 µ /L) and AST (up to 120 µ/L) in serum as reported by Randox (2008).

Complete blood count of experimental rats

The packed cell volume (% PCV) of blood of experimental rats are shown (Table 2). Average PCV (%) ranged from 43.5-47.0% for rats fed PAR and SNR extracts (Groups 1-4), and control (39.2 - 45.6%). The PCV values showed that the rats had adequate blood volume sufficient enough to prevent the occurrence of pale occular vessels, based on the recommended PCV values of not less than 35% as satisfactorily adequate for animals including humans (Davies *et al.,* 1984). Haemoglobin (Hb) concentration ranges from 14.1-14.6g/100mL for rats (Groups 1-4) fed with extracts of both PAR and SNR banana. The Hb concentration of the control group, 14.5 ± 0.11gHb/100mL (Group 5) was significantly different ($p>0.05$) from those of the experimental rats. Haemoglobin level up to 10g/100mL is recommended (Davies *et al.,* 1984) as adequate to prevent anaemia and wasting symptoms. Therefore, Hb level in experimental rats (greater than 10g/100mL) showed that the banana extracts did not affect the Hb levels of the experimental rats.

The average red blood cells (Rbc) ranged from 7.3-7.8 x 106 WL and white blood cell (Wbc) from 6,290 - 9,612 x µ/L for experimental rats (groups l-4) fed PAR and SNR and the control. These values were not significantly different ($p>0.05$). However, the Rbc values increased with increase in concentration of SNR banana extract (7.3-7.7 x 10^6 µ/L) and was higher than that of the control (6.5± 0.01 x 10^6 µ/L). This SNR banana extract probably contributed more dietary iron to the diet which increased with concentration to build haemoglobin.

The average platelet number (105,500-137,000) of the experimental rats and the control did not show any significant difference ($p>0.05$). Similarly, the average lymphocytes (65.3- 73.0%), neutrophiles (26.0 - 32.0%), eonocytes (1.5-2.4%) and eosinophile (1.8-2.8%) values were not significantly different ($p > 0.05$) from those of the control.

Effect of banana powder extract on the organs of experimental rats

The histopathology results of the experimental rats' tissue organs are shown in Table 3 and Plates 1 and 2.

The Liver: Rats in groups 1-4 fed SNR and PAR banana extracts generally showed moderately congested hepatocellular sinusoids, separation of sheets of hepatic cords, slight distortion of architecture, thinning of hepatic cords probably due to cutting of tissue and no visible lesions (NVL). While the control (group 5) showed similar features of the liver, except individualization of hepatocytes. The different concentrations of banana extract (150-1000mg) did not affect the liver, because there were no lesions formed which are symptoms of toxic effect.

The brain: The experimental rats in groups 1-4 fed PAR and SNR extracts and the control (group 5) showed no visible lesion, moderate congested vessels and artifacts, and therefore the two banana extracts, regardless of their concentrations up to 1000 mg/kg body weight did not affect the brain.

Heart: Experimental rats in groups 1-4 fed PAR banana extract had congested heart chambers, no visible lesions, myocardium in shreds while the SNR fed rats also showed congested chambers, no myocardial degeneration, no visible lesions. The control rats also showed congested heart chambers and no lesions. The congested chambers could be due to mere physical factors such as restricted movement and ventilation rather than clinical.

Kidney: The kidneys of rats fed with PAR and SNR extracts (groups 1-4) and the control (group 5) had moderate tubulorrhexis and congestion, no visible lesions, moderate sloughing of renal tubular epithelium. Generally, no significant lesions were formed and therefore no impairment of kidney, which is an indication of normal functioning. This is based on the values of creatinine in blood serum of experimental rats (0.6 ± 0.00mg/dL, Table 2) which were within the recommended limits (0.3-0.9mg/dL). Hence, the banana extracts (PAR and SNR) may be adjudged nontoxic to the kidney.

Intestine: The intestine of experimental rat (groups 1-4) fed PAR and SNR banana extracts showed fairly normal architecture, intact, moderate epithelia and enterocyte sloughing, eosinophilic debris within the luma, villi appeared fairly normal and few cases of slight necrosis of villi and no visible lesions. The control rats generally showed mild sloughing of enterocyte and villi, increased number of lymphocytes in lamia proprial. The occurrence of sloughing of villi and epithelium and artifacts autolysis even in the experimental rats and control could be due to cutting during harvesting of tissue rather than toxic effect of extract since it occurred in the control without any banana extract.

CONCLUSION

Foam-mat dried banana powder (PAR and SNR) incorporated with glycerylmonostearate (GMS) at 0.4% as foaming agent did not constitute any toxicological risks based on biochemical and histopathological parameters obtained from experimental rats.

CONFLICT OF INTERESTS

The authors declare no conflict of interests.

CONTRIBUTION OF AUTHORS: OCO and FKO were responsible for the experimental

and project design and made conceptual contributions. AR also gave some conceptual contributions. ESID and EB did the histopathological analysis. OCO prepared the first manuscript. All authors read and approved of the final manuscript.

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Table 1: Biochemical parameters of blood serum of experimental rats

		Treatments				
Parameter	**Sample**	**GP1**	**GP2**	**GP3**	**GP4**	**GP5**
Protein	PAR	6.9±0.01^{e}	7.2+0.03^{e}	7.0±0.01^{e}	7.2±0.01^{e}	7.3±0.04^{e}
(gm/dL)	SNR	7.4±0.02^{e}	7.1±0.01^{e}	6.9±0.04^{e}	6.8±0.02^{e}	6.8±0.01^{e}
Albumin	PAR	4.3+0.009^{f}	4.3+0.01^{f}	4.3±0.01^{f}	4.4±0.05^{f}	4.3±0.02^{f}
(gm/dL)	SNR	4.4±0.05^{f}	4.4+0.03^{f}	4.5±0.06^{f}	4.1±0.01^{f}	4.0±0.03^{f}
Globulin	PAR	2.8+0.008^{g}	2.9±0.007^{g}	3.0±0.01^{g}	2.8+0.009^{g}	3.0±0.007^{g}
(gm/dL)	SNR	3.0±0.006^{g}	2.7±0.01^{g}	2.5±0.008^{g}	2.7±0.01^{g}	2.8±0.008^{g}
A.G	PAR	1.5±0.003^{s}	1.5+0.009^{s}	1.4±0.01^{s}	1.6±0.007^{s}	1.6±0.005^{s}
ratio	SNR	1.5±0.001^{s}	1.6±0.003^{s}	1.7+0.02^{s}	1.6±0.006^{s}	1.4±0.003^{s}
AST	PAR	42±0.14^{h}	43±0.21^{h}	40±0.20^{h}	44±0.22^{h}	43±0.18^{h}
(µ/L)	SNR	38±0.11^{i}	43±0.18^{h}	42±0.19^{h}	45±0.23^{h}	43±0.20^{h}
ALT	PAR	26±0.13^{i}	28±0.15^{i}	30±0,11^{i}	28±011^{i}	28±0.13^{i}
(µ/L)	SNR	26±0.11^{i}	29±0.13^{i}	27±0.13^{i}	29±0.16^{i}	28±0.11^{i}
ALP	PAR	92±0.21^{k}	77+0.19^{j}	77±0.20^{j}	86±0.11^{k}	82±0.13^{j}
(µ/L)	SNR	80±0.19^{j}	76±0.15^{j}	85±0.17^{k}	85±0.14^{k}	88±0.11^{k}
Creatinine	PAR	0.50±0.003^{g}	0.35±0.007^{h}	0.56±0.005^{c}	0.60±0.001^{g}	0.42±0.03^{h}
(mg/dL)	SNR	0.28±0.001^{i}	0.40±0.002^{h}	0.28±0.003^{c}	0.45±0.002^{h}	0.25±0.003^{l}
Glucose	PAR	120±0.23^{n}	121±0.21^{n}	123±0.16^{n}	126±0.21^{n}	118±0.31^{n}
(mgldL)	SNR	120±0.27^{n}	122±0.18^{n}	122±0.11^{n}	127±0.18^{n}	120±0.26^{n}
Rat Weight	PAR	15.1±0.07^{a}	25.7±0.1^{b}	15.8±0.12^{a}	31.0±0.07^{b}	10.1±0.08^{c}
Increase	SNR	28.0±0.05^{a}	41 .8±0.08^{d}	24.4±0.03^{b}	29.5±0.11^{b}	8.7±0.01^{c}
(%)						

Values represent average of 5 measurements (±SEM)
Means in a row with the same letter are not significantly different ($p > 0.05$)
Means in a row with different superscripts are significantly different ($p<0.05$)
GP1 : 150mg Banana extract/kg bodyweight
GP2 : 250mg ” ” ”
GP3 : 750mg ” ” ”
GP4 : 1000mg ” ” ”
GP5 : 3mL Distilled water/rat (control)
PAR : Chinensis Banana Powder with GMS foam agent
SNR : Giant Cavendish banana powder with GMS foam agent.
AST : Aspartate aminotranferase
ALT : Alanine aminotransferase
ALP : Alkaline phosphatose

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Table 2: Complete Blood Count Analyses of Experimental Rats' Blood Serum

Parameter	Sample	GP1	GP2	GP3	GP4	GP5
PCV %	PAR	44.0±0.13^{a}	43.5±0.11^{a}	45.4±0.18^{a}	47.0±0.22^{a}	45.6±0.17^{a}
	SNR	45.0±0.11^{a}	46.0±0.15^{a}	46.0±0.21^{a}	45.0±0.19^{a}	39.2±0.21^{a}
Hb	PAR	14.1±0.16^{b}	14.2±0.11^{b}	14.6±0.13^{b}	14.2±0.09^{b}	14.5±0.11^{b}
(g/mL)	SNR	14.3±0.13^{b}	15.0±0.19^{b}	14.5±0,11^{b}	14.5±0.14^{b}	12.4±0.17^{b}
Rbc	PAR	7.3±0.001^{c}	7.4±0.005^{c}	7.7±0.01^{c}	7.8±0.02^{c}	7.6±0.01^{c}
(X10^{6} µL)	SNR	7.3+0.003^{c}	7.8±0.04^{c}	7.8±0.003^{e}	7.9±0.05^{c}	6.5+0.01^{c}
Wbc	PAR	8,380^{d}	6,263^{e}	8,620^{d}	9120^{d}	9,790^{d}
(X10^{3} µL)	SNR	7,238^{d}	6,290^{e}	9,612^{d}	6,838^{d}	8,700^{d}
Platelet	PAR	119,600^{f}	105,500^{g}	137,200^{f}	125,200^{f}	129,800^{f}
	SNR	116,500^{f}	105,600^{g}	121,800^{f}	107,000^{f}	120,000^{f}
Lymp	PAR	66.8±0.11^{h}	70.3±0.019^{h}	63.8±0.10^{h}	68.0±0.13^{h}	69.0±0.20^{h}
(%)	SNR	65.3±0.16^{h}	53.0+0.11^{h}	67.8±0.13^{h}	69.5±0.10^{h}	73.0±0.16^{h}
Neuro	PAR	28.6±0.11^{i}	26.0±0.13^{i}	32.0±0.15^{i}	26.8±0.10^{i}	26.8±0.14^{i}
%	SNR	31.0±0.10^{i}	38.8±0.11^{i}	27.8±0.13^{q}	26.3±0.13^{i}	23.0±0.11^{j}
Mono	PAR	2.0±0.02^{l}	1.5±0.01^{l}	1.2±0.07^{m}	2.0±0.01^{l}	2.4±0.01^{k}
(%)	SNR	2.0±0.01^{l}	2.6±0.01^{k}	1.8±0.05^{l}	1.8±0.03^{l}	1.5±0.02^{m}
Eos	PAR	2.6±0.01^{p}	1.8±0.04^{n}	3.2±0.06^{p}	2.4±0.01^{p}	1.8±0.03^{n}
	SNR	1.8±0.02^{n}	1.6±0.01^{n}	2.8±0.07^{p}	2.2±0.03^{q}	2.5±0.05^{p}

Values represent average of 5 measurements (±SEM)
Means in a row with the same letter are not significantly different ($p > 0.05$)
Means in a row with different superscripts are significantly different ($p<0.05$)
GP1 : 150mg Banana extract/kg bodyweight
GP2 : 250mg " " "
GP3 : 750mg " " "
GP4 : 1000mg " " "
GP5 : 3mL Distilled water/rat (control)
PAR : Chinensis Banana Powder with GMS foam agent
SNR : Giant Cavendish banana powder with GMS foam agent.

Table 3: Histopathology Report of Experimental Rats' Tissue Organs

	TREATMENT				
Organ	Group 1	Group 2	Group 3	Group 4	Group 5 (Control)
Liver	1s33 Lv: moderate hepatocellular degeneration; congested sinusoids	2p43 Lv: separation of sheets of hepatic cords.	3p33 Lv: moderate centrilobular hepatocellular degeneration	UL Lv: congested sinusoids; pale staining (?AA)	5s52 Lv: Individualization of hepatocytes;
	1s24 Lv: marked congestion of sinusoids; moderate degeneration of centriloular hepatocytes	2s43 Lv: Moderately congested sinusoids	3p11 Lv: NVL	4p21 Lv: AA, congestion	5s13 Lv: Thinning of hepatic cords
	1p31 Lv: Slight distortion of architecture; congested sinusoids	2s23 Lv: fairly normal	3s51 Lv: NVL	4s52 Lv: marked congestion; inflammatory cellular aggregates at periportal areas	5p11 Lv: thinning of hepatic cords
	1p51 Lv: AA; thinning of hepatic cords	2p23 Lv: AA			5p54 Lv: moderate congestion of central veins;
		2s11 Lv: thinning of hepatic cords			5s25 Lv: NVL
Brain	s1 Br: AA	2s13 Br: AA	5p52 Br: NVL	4p53 Br: NVL	5p33 Br: AA
	1s32 Br: NVL	2p45 Br: NVL	3p13 Br: NVL	4s51 Br: NVL	5s51 Br: NVL
	1s23 Br: Moderate congestion	2s42 Br: congested vessels	UL Br: marked congestion	4p23 Br: congested vessels	5s21 Br: NVL
	1p12 Br: focal, neuronal	2s22 Br: NVL	3s52 Br: NVL	4s51 Br: NVL	
Heart	1s33 Ht: myocardial depletion/ congested heart chambers.	2s43 Ht: congested chambers and myocardial vessels	3p11 Ht: NVL	UL Ht: markedly congested heart chambers	5p31 Ht: Marked congestion of chambers

Table 3 Cont.

	Group 1	Group 2	Group 3	Group 4	Group 5
	1s24 Ht: markedly congested chambers; No myocardial degeneration	2s23 Ht: NVL	3p32 Ht: NVL	4p21 Ht: myocardium in shreds (?AA)	5s13 Ht: NVL
	s4 Ht: NVL	2p23 Ht: NVL	3p51 Ht: NVL	4s52 Ht: marked congestion of heart chambers	5p11 Ht: NVL
	1p42 Ht: congested heart chambers	2s12 Ht: NVL	3s51 Ht: marked congestion; myocardium is in shreds (?AA)	4p51 Ht: marked congestion of chambers	5p54 Ht: markedly congested heart vessels/chambers
					5s22 Ht: markedly congested chambers
Kidney	1s22 Kd: moderate tubulorrhexis	2s15 Kd: moderate renal tubular epithelial necrosis	3p31 Kd: mild sloughing of the renal tubular epithelium	4p24 Kd: AA	5s52 Kd: moderate tubular epithetlial necrosis
	s2 Kd: moderate congestion	2p21 Kd: moderate tubular epithelial necrosis	3p54 Kd: moderate necrosis of renal tubules	4s53 Kd: NVL	5s12 Kd: moderate sloughing of renal tubules
	1s31 Kd: moderate congestion of vessels within renal medulla	2s41 Kd: moderate focal tubular epithelial necrosis	3p12 Kd: moderate necrosis of tubules	4p32 Kd: moderate renal tubular epithelial necrosis	5s23: Kd: widespread moderate tubular epithelial necrosis
	1p41 Kd: slight sloughing of renal tubular epithelium	2s24 Kd: extensive necrosis of tubules	3s54 Kd: moderate congestion	5p14 Kd: tissue is pale-staining (possibly AA);	5p51 Kd: moderate congestion,
Intestine	1s21 In: diffuse necrosis of the enterocytes; distorted architecture.	2s14 In: Eosinophilic debris within the lumen; villi appear fairly normal	3p53 In: moderate necrosis of enterocytes; necrotic debris is present within the lumen	4p52 In: NVL	5s11 In: NVL
	1s34 In: moderate epithelial /sloughing	2p22 In: severe villi atrophy/necrosis	3s11 In: NVL	4p22 In: severe distortion of architecture; necrosis of villi	5p13 In: moderate sloughing of villi; increased numbers of lymphocytes in lamina propria
	Group 1	Group 2	Group 3	Group 4	Group 5
	1S5 In: NVL	2s44 In: slight necrosis and sloughing of enterocytes at the apex of the villi	3p14 In: severe villi atrophy/necrosis	4s54 In: AA	5p53 In: mild sloughing of enterocyte
	1p11 In: slight necrosis of enterocytes	2s21 In: fairly normal architecture	3s53 In: sloughing of enterocyte; no visible villi		5s24 In: much sloughing of enterocytes
		2p44 In: NVL	3s53 In: slight sloughing of enterocytes; villi necrosis		

Key:

Br: Brain
Ht: Heart
In: Intestine
Kd: Kidney
Lv: Liver
UL: Unlabelled slide
NVL: No visible lesion

AA: Artefact/Autolysis
P: Chinensis banana (PAR) powder with Gms foam agent.
S: Giant Cavendish banana (SNR) powder with Gms foam agent.

Figure 1: The heart of the rat fed with 150 mg extract of SNR banana/kg weight (1S24) showing congested vessels Mag X 400 H&E

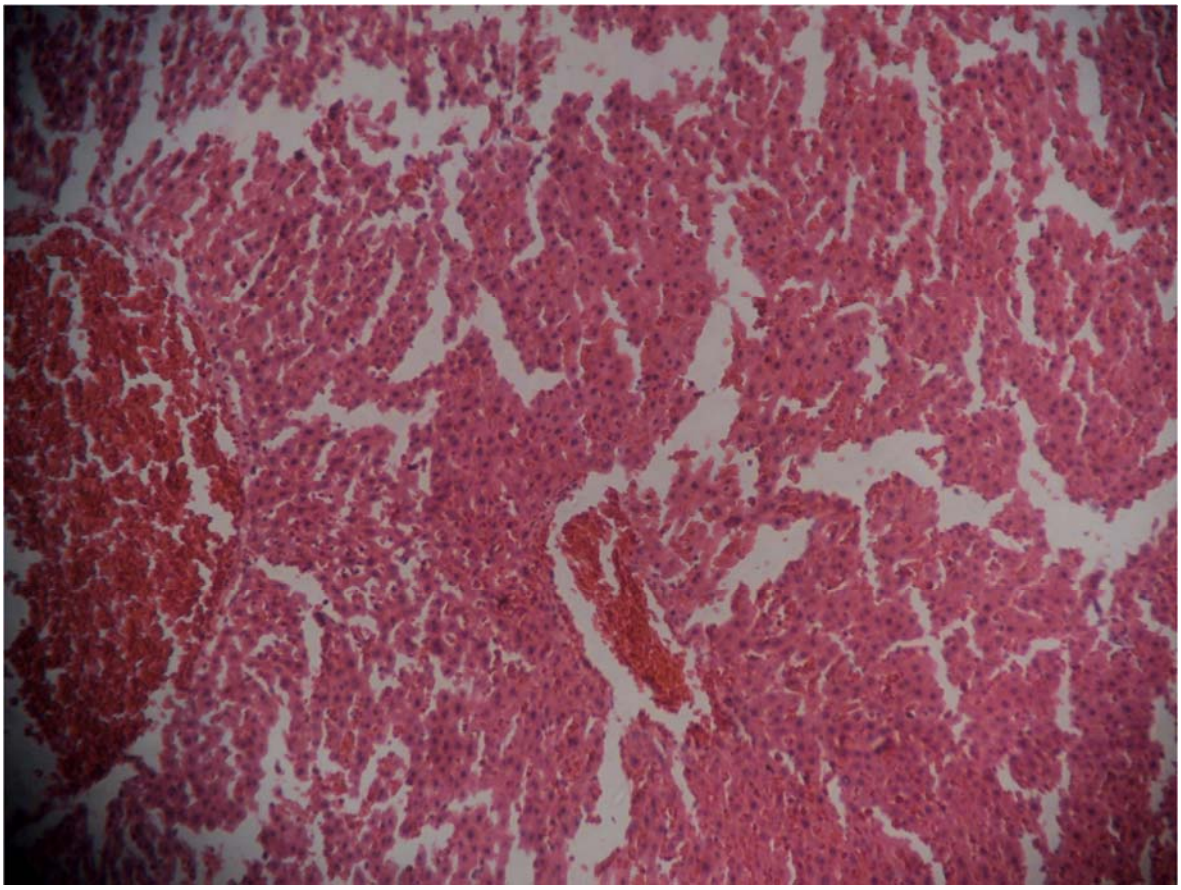

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Figure 2: **The kidney of the rat fed with 250 mg extract of PAR banana / kg body weight (kd 2P21) showing congested vessels Mag X 400 H&E**